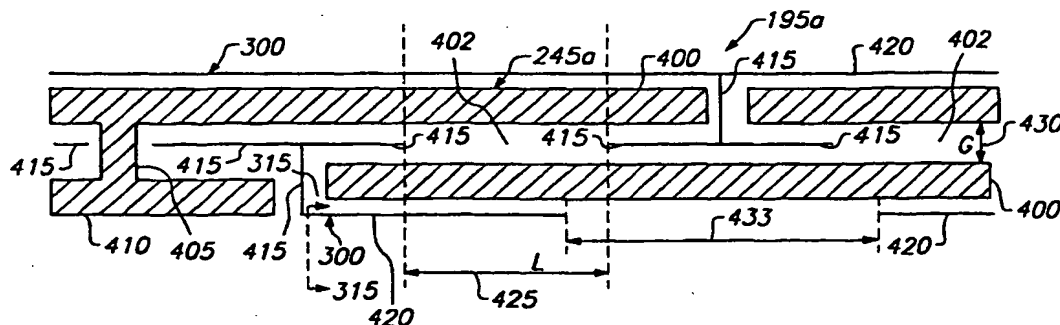




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(54) Title: TOUCH SENSITIVE SCREEN AND ITS MANUFACTURING METHOD



## (57) Abstract

A position touch sensor has a substrate and a resistive layer disposed on the substrate. At least one pair of electrodes is positioned on the resistive layer. A portion of one electrode is spaced from a portion of another electrode to produce an overlapped resistive region between the spaced portions of the electrodes. An insulating region extends into and terminates in the overlapped resistive region from a resistive region of the resistive layer outside the overlapped resistive region.

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## TOUCH SENSITIVE SCREEN AND ITS MANUFACTURING METHOD

## FIELD OF THE INVENTION

The present invention relates to devices for sensing the X-Y coordinates of a touch on a surface thereof. The present invention more particularly provides a resistive touch-screen whereby touch coordinates can be determined with excellent linearity throughout an increased proportion of its touch-sensitive area. The present invention also provides a method for producing a touchscreen having reduced bow, or reduced variation of bow, of equipotential field lines therein.

## BACKGROUND OF THE INVENTION

A touchscreen is an input device, placed over a display such as a cathode ray tube (CRT) or a liquid crystal display, for sensing the two-dimensional position of the touch of a finger or other electronically passive stylus. Such systems are provided for many applications including restaurant order entry systems, industrial process controllers, interactive museum exhibits, public information kiosks, lap-top computers, etc. Many schemes have been proposed for touchscreen construction. Presently, the commercially dominant touch technologies are 4-wire resistive, 5-wire resistive, capacitive, and ultrasonic.

5-Wire resistive touchscreens, e.g. the AccuTouch<sup>TM</sup> product line of Elo Touch-Systems, Inc., of Fremont, California, are widely accepted for many touchscreen applications. Mechanical pressure from a finger or stylus causes a plastic membrane coversheet to flex and make physical contact with an underlying glass substrate, coated with a resistive layer upon which voltage gradients are excited. Via electrical connections to the four corners of the glass substrate, associated electronics can sequentially excite gradients in both the X and Y directions. The underside of the coversheet has a conductive coating which provides an electrical connection between the touch location and voltage sensing electronics. There are a total of five electrical connections, i.e., "5 wires", between the touchscreen and the controller electronics. Further details regarding 5-wire touchscreens are found in the US 4,220,815; 4,661,655; 4,731,508; 4,822,957; 5,045,644; and 5,220,136.

4-Wire resistive touchscreens have lower manufacturing costs than 5-wire ones and dominate the low-end market. However, in applications demanding durability, the 5-wire technology is superior. To measure X and Y coordinates, 4-wire touchscreens alternate between exciting a voltage gradient on the substrate resistive coating and exciting an orthogonal voltage gradient on the coversheet coating. Performance of 4-wire touchscreens degrades as the uniform resistivity of the coversheet coating is lost as a result of repeated flexing. This is not a problem for 5-wire touchscreens where both X and Y voltage gradients are generated on the substrate's resistive coating, and the coversheet coating need only provide electrical continuity. However, in a 5-wire touchscreen, a peripheral electrode pattern of some complexity is required to enable sequential generation of both X and Y voltage gradients on the same resistive coating. This is a major reason why 5-wire touchscreens are costlier to manufacture than 4-wire ones.

In a 5-wire touchscreen the substrate typically comprises about 1.0 mm to about 3.0 mm thick glass, on which has been applied the resistive coating, typically indium tin oxide (ITO), as well as a peripheral electrode pattern. The peripheral electrode pattern forms a resistor network which is powered at the four corners by excitation voltages from controller electronics. In turn, the electrode pattern excites voltage gradients in the ITO corresponding to the touchscreen active area. A key issue is minimization the cost of this coated and patterned substrate component.

Conductive traces connect the four corners of the electrode pattern to a group of soldering pads where a simple five-wire ribbon cable is connected. This reduces the cost of the fully assembled touchscreen by eliminating the need for a complex cable harness and wire routing. A screen-printed silver frit is the typical material for these traces due to its high conductivity, durability, and its ability to accept solder connections. The silver-frit traces are isolated by nearby insulating regions of bare glass substrate. Hence the glass substrate has three components: conductive regions upon which silver frit has been sintered, insulating regions of bare glass, and resistive regions coated with ITO.

Commercially, the peripheral electrode pattern may be created via geometrical arrangements of the aforementioned three ingredients. To control costs, the resistive ITO coating in the peripheral electrode region is created in the same manufacturing step and

with the same nominal electronic characteristics as in the region in where X and Y voltage gradients are generated. An example is the electrode design given in Figure 1C herein, reproduced from US 5,045,644. Such electrode designs that only use the above mentioned materials play a key role in state-of-the-art 5-wire touchscreen technology.

5           A quality 5-wire touchscreen will generate X,Y coordinates that accurately correspond to the touch position. Accuracy is largely determined by the "linearity" of the touchscreen. In the ITO coating within the touch region of an ideally linear touchscreen, the contours of equal voltage, i.e. equipotential lines, are equally spaced straight lines orthogonal to the X or Y coordinate being measured. Deviations from linearity occur in practice.  
10       The design of the peripheral electrode pattern may not be fully optimized. Also, manufacturing variations in the uniformity of the ITO coating cause deviations from ideal linearity. A central problem for 5-wire resistive technology is to find the most cost-effective way to achieve sufficient linearity to meet marketplace demands.

          One approach is to insist on tight manufacturing tolerances for the uniformity of the  
15       resistivity of the ITO coating. This assures quality product performance but has the disadvantage of driving up the cost of the ITO coating process.

          Another approach is to design the peripheral electrode patterns to be more tolerant to variations in ITO resistivity. This approach generally leads to increased current draw through the electrode pattern. This is undesirable in many applications as it places greater  
20       power demands on the associated controller electronics. This approach may also lead to an increased width of the peripheral electrode pattern.

### BRIEF SUMMARY OF THE INVENTION

          Therefore, what is needed and what has been invented is an electrographic touch sensor and method which compensate for batch-to-batch variations in the resistive layer and  
25       for the limitations of the in-place electrodes — in particular, a resistive touch sensor and method for controlling the flow of current through a resistive layer for converting physical position information on the resistive layer into electrical signals by modifying the resistance characteristics of the resistive layer.

The present invention accomplishes its desired objects by broadly providing a position touch sensor comprising a resistive surface (i.e., an impedance surface) having resistive perimeter edges; and at least one pair of electrodes disposed on, and electrically connected to, the resistive surface. The position touch sensor further includes at least one  
5 pair of spaced electrode segments to provide generally opposed boundaries for defining an overlapped resistive region between the spaced electrode segments. The resistive surface has at least one insulating region (e.g., a void, an insulating segment or channel, etc.) commencing from a resistive point in the resistive surface exterior to the overlapped resistive region and terminating in the overlapped resistive region.

10 The present invention further accomplishes its desired objects by also broadly providing a method of modifying the resistance characteristics of a resistive layer between a pair of parallel electrode segments of a position touch sensor comprising the steps of:

a) providing a position touch sensor comprising a substrate having adherently deposited thereon a resistive layer having a resistive portion, and at least one pair of  
15 generally parallel spaced electrode segments positioned on, and electrically connected to, the resistive layer and including an overlapped resistive region between the generally parallel spaced electrode segments and integrally contained within the resistive layer such that the overlapped resistive region includes the resistive portion with the overlapped resistive region indiscreetly merging with an external resistive region outside of the  
20 overlapped resistive region and integrally contained within the resistive layer such that the external resistive region includes the resistive portion; and

b) altering the resistive portion of the overlapped resistive region and of the external resistive region.

The present invention also further accomplishes its desired objects by also further  
25 broadly providing a method for controlling the flow of current through a resistive layer for converting physical position information on the resistive layer into electrical signals comprising the steps of:

a) providing a resistive layer for converting physical position information thereon into electrical signals;

- b) determining through the use of electrical excitation in the resistive layer a dimension of a length of a generally continuous resistive section which is to be located in the resistive layer of step (a);
- c) disposing a first insulating region in the resistive layer of step (a) to form a first boundary of the generally continuous resistive section; and
- d) disposing, at a distance from the first insulating region essentially equaling the dimension of step (b), a second insulating region in the resistive layer of step (a) to form a second boundary of the generally continuous resistive section such that current may be conducted through the generally continuous resistive section between the first insulating region and the second insulating region.

### BRIEF DESCRIPTION OF THE DRAWING(S)

Figs. 1A and 1B are drawing illustrating, respectively, a "ruler line plot" and the equipotential lines as obtained using the gradient sheet of a conventional touchscreen;

Fig. 1C is a top elevational view of another conventional gradient sheet having plural overlapping conductive strips communicating with plural T-shaped electrodes;

Fig. 2A is a top elevational view of another conventional gradient sheet having a resistive element/electrode configuration to reduce bow equipotential field lines therein;

FIG. 2B is a partial top elevational view which illustrates the spacing of the resistance elements/electrodes shown in Fig. 2A;

Fig. 3 is a schematic diagram of a resistive touchscreen system, while Fig. 4 is a perspective view of a CRT incorporating the resistive touchscreen system of Fig. 3;

Fig. 5 is a segmented perspective view of the touchscreen of Fig. 3 incorporating the present invention;

Fig. 6 is a top plan view of a portion of a gradient sheet having a resistor chain comprising overlapping conductive strips with a conductive lead coupling a T-shaped electrode to one of the conductive strips and including an insulating region having an insulating region portion extending into and terminating in an overlapped resistive region between the overlapping conductive strips and communicating with another insulating region portion which extends outside of the overlapped resistive region;

Fig. 6A is a top plan view of another embodiment of the Fig. 6 gradient sheet;

Fig. 6B is a partial vertical sectional view of a gradient sheet including a substrate supporting a semiconductive resistive layer which has been altered by the formation of a channel therein to provide an insulating zone in the semiconductive resistive layer;

5 Fig. 6C is a partial vertical sectional view of a gradient sheet including a substrate supporting a semiconductive resistive layer altered by the formation of another channel therein to provide another insulating zone in the semiconductive resistive layer;

Fig. 7 is a top plan view of a portion of a gradient sheet having a resistor chain comprising a plurality of conductive strips serially disposed in proximity to an edge of the  
10 gradient sheet with any two contiguous conductive strips spaced by an overlapped resistive region and having a pair of opposed insulating region portions extending into and terminating in the overlapped resistive region with the pair of opposed insulation region portions each communicating with an insulating region outside of the overlapped resistive region;

Fig. 8 is a top plan view of a portion of a gradient sheet having a resistor chain  
15 comprising overlapping conductive strips having an overlapped resistive region between conductive strips and including T-shaped insulating regions partly disposed outside of the overlapped resistive region and partly extending into and terminating in the overlapped resistive region with the portion of the T-shaped insulating region extending into the overlapped resistive region having an insulating subsection which is generally parallel to  
20 the overlapping conductive strips;

Fig. 9 is a top plan view of another embodiment of the Fig. 8 gradient sheet but with the insulating subsection communicating with another insulating subsection which is generally normal thereto and terminating in and contacting two contiguous opposed overlapping conductive strips within the overlapped resistive region and with the portion of  
25 the T-shaped insulating region disposed outside of the overlapped resistive region terminating in and making contact with the same two opposed contiguous overlapping conductive strips outside of the overlapped resistive region;

Fig. 10 is a top plan view of another embodiment of the Fig. 9 gradient sheet with the other insulating subsection overlapping the two opposed contiguous overlapping  
30 conductive strips within the overlapped resistive region and with the T-shaped insulating



region disposed outside of the overlapped resistive region overlapping the two opposed contiguous overlapping conductive strips at an angle thereto;

Fig. 11 is a top plan view of a gradient sheet having the resistor chain and insulating region of Fig. 9 thereon; and

5 Fig. 12 is a schematic side elevational view of a capacitive touchscreen embodiment of the present invention having a substrate covered by a resistive layer upon which are a plurality of conductive electrodes, in turn are covered by a dielectric layer, with a portion of the resistive layer having been removed to form an insulating zone.

### DETAILED DESCRIPTION OF THE INVENTION

10 Referring in detail now to the drawings wherein similar parts of the present invention are identified by like reference numerals, there is seen in Figs. 1A-2B various prior art gradient sheets which are intended to reduce the curvature (i.e., "bow") produced by the voltage drop along a resistor network attached to resistive electrodes in a direction perpendicular to the applied voltages. The performance of any touch sensitive screen can  
15 be demonstrated with what is known as a "ruler line plot," which is what a rectangular set of lines would look like if impressed upon the sensor, and an "equipotential line plot" showing the location of equal potentials on the sensor. For example and as best described in US 5,045,644, Fig. 1A shows a ruler line plot 50 on a gradient sheet 52 of the sensor, while Fig. 1B shows an equipotential line plot 55 on gradient sheet 52. These line plots  
20 shown, typically, represent each 0.1 volt differences. There is substantial ripple 60 along edges 65 of gradient sheet 52, and particularly near corner 67. Ruler line plot 50 only has straight lines 70 at a significant distance from edges 65. The area of straight lines 70 defines the linear portion of gradient sheet 52.

US 5,045,644 also discloses another prior art gradient sheet, represented in Fig. 1C  
25 as a gradient sheet 195' having a central uniform resistive layer 205 of, for example, two hundred ohms per square. Positioned along each edge of the surface of gradient sheet 195' is a resistor chain 245', formed of a series of overlapping conductive strips 350. Using these overlapping conductive strips 350 and the resistivity of resistive layer 205, the specific resistances of resistor chain 245' can be tailored for a particular application and distri-

5      bution of voltages along the edges of gradient sheet 195'. Conductive strips 350 are physically attached to resistive surface 205 by depositing a conductive material, e.g., silver frit, in the appropriate pattern. A conductive corner tab 355 applies a voltage to the end of resistor chain 245', and a conductive lead 360 typically connects conductive corner tab 355 to a tab (not shown) at another location of gradient sheet 195'. This connection between the conductive corner tabs can be external to gradient sheet 195'. Conductive corner tab 355 is connected to appropriate external circuitry for supplying the voltage source.

10      US 5,045,644 further discloses a plurality of T-shaped electrodes (or "tees") 365 spaced along the edges of resistive layer 205. A conductive lead 370 connects a T-shaped electrode 365 to resistor chain 245'. The position of conductive leads 370 along resistor chains 245' is selected to provide the appropriate reference voltage to T-shaped electrodes 365. The length and spacing of T-shaped electrodes 365 are chosen to compensate for any cumulative voltage drop along resistor chain 245' portion which is perpendicular to the current flow on resistive layer 205. Elongated regions 300 of high resistance, produced by no deposit of resistive layer 205 on gradient sheet 195', are aligned with and interspersed between the bases of T-shaped electrodes 365. This substantially isolates the main portion of resistive layer 205 from that portion 205a in the region of resistor chains 245'. The spacings and effective lengths of T-shaped electrodes 365 are selected to produce a voltage gradient at each T-shaped electrode 365 to compensate for any voltage drop which occurs along resistor chain 245'.

20      Referring now to Figs. 2A and 2B, which illustrate a prior art gradient sheet from US 4,822,957, there are seen conductive electrodes 85 positioned along the edges of a resistive layer 84 of gradient sheet 86. Additional conductive electrodes 88 are positioned along each edge, with each electrode 88 being joined to an adjacent conductive electrode 85 by a conductive connector or lead 90. The spacing and effective lengths of electrodes 88 are selected to produce a voltage gradient at each electrode 88 to compensate for any voltage drop that occurs along the resistance elements between conductive electrodes 85. A pair of overlapping conductive legs 92, 94 overlap a length L' and are spaced apart a distance D (Fig. 2B). The resistance produced at each overlap between conductive electrodes 85 is a function of D, L', and the resistivity of resistive layer 84. The patent teaches

that the location of the connection between conductive electrode 85 and electrode lead 90 is not critical, as long as the resistance of each conductive electrode 85 is sufficiently low.

Fine tuning of the resistance of each overlap between conductive electrodes 85 can be achieved by shortening or lengthening one or both of conductive legs 92, 94 to change  $L'$ .

5 This can be accomplished readily by changing the artwork used for screen printing techniques. To prevent undesirable current flow between conductive electrodes 85 and conductive electrodes 88, a line 87 of discontinuity is formed between conductive electrodes 85 and 88. Line 87 is where there is no resistive layer 84 and represents a discontinuity in resistive layer 84. Line 87 produces a central resistive area 84A and a peripheral resistive  
10 area 84B, and is taught as being formed by either not depositing any resistive layer 84 along line 87 or removing portions of resistive layer 84 after application. In either case conductive connectors 90 span or bridge line 87 so as to connect conductive electrodes 88 to conductive electrodes 85. Line 87 is placed on gradient sheet 86 before the placement of conductive electrodes 85 and conductive electrode 88 on resistive layer 84 and does not  
15 serve to determine the resistance value of the overlapped region between overlapping conductive legs 92 and 94 of conductive electrodes 85, but rather serves to isolate this overlapped region from central resistive area 84A.

Referring in detail now to Figs. 3-12 of the drawings for preferred embodiments of the present invention, in Fig. 3 there is seen a generalized system diagram of a resistive  
20 touchscreen system 100. Resistive touchscreen system 100 includes a touchscreen 105 coupled via controller electronics 110 to a host computer 115. Generally, controller electronics 110 receives from touchscreen 105 analog signals carrying touch information. Controller electronics 110 also sends to touchscreen 105 excitation signals. Specifically, controller electronics 110 applies a voltage gradient across a resistive layer 205 (see Fig. 5)  
25 which is disposed on a substrate 200 of touchscreen 105. The voltages at the point of contact are the analog representations of the position touched. Controller electronics 110 digitizes these voltages and transmits these digitized signals, or touch information in digital form based on these digitized signals, to host computer 115 for processing.

As best shown in Fig. 4, touchscreen 105 may be installed in a conventional display  
30 device such as a CRT 145. Touchscreen 105 is placed in front of CRT face 150 of host

computer 115 and under CRT monitor bezel 155. A plurality of spacers 111 is conveniently provided in order to create a gap for touchscreen 105 between CRT monitor bezel 155 and CRT face 150. A high voltage anode 117 (not fully shown in Fig. 4) is coupled to a CRT circuit board 113 via an electrical cable 139. A touchscreen ribbon cable 131 connects from touchscreen 105 to an outlet 133 which is to receive electrical power and which is to interfaces with controller 110 (not shown). A ground strap 129 connects from a chassis ground 147 to outlet 133. Display device 145, along with CRT circuit board 113 and associated cables, are all received by a generally hollow monitor back case, illustrated as 121. Preferably, the components of touchscreen 105 are substantially transparent so that the two dimensional graphics or data projected by CRT face 150 is seen therethrough.

Alternatively, resistive touchscreen system 100 may be installed in other suitable types of display devices, such as a liquid crystal display monitor.

Controller electronics 110 may be a separate electronics module, such as Elo Model E271-140 AccuTouch™ controller, from Elo TouchSystems or may be largely embedded in host computer 115, such as the digitizer panel interface contained in central processing unit (CPU) chip of a handheld computer system based on Intel 1386™ EX Embedded Microprocessor MHT9000 Handheld Terminal. Other controller options are also possible.

Controller electronics 110 may perform various functions. For example, it may excite the electrode pattern and measure the voltage on cover sheet 210 (see Fig. 5 ) of touch screen 105. This function is performed by the aforementioned Elo Model E271-140 AccuTouch™ controller. Alternatively, controller electronics 110 may connect cover sheet 210 to a current source, ground the four corners of the electrode pattern on cover sheet 210, and digitize the currents for the electrode-pattern corners. As another option, controller electronics 110 may support AC operation of the invention by driving the four electrode-pattern corners with an AC signal having a fixed voltage amplitude, replacing coversheet 210 with a thin dielectric coating 725 (Fig. 12) applied directly to resistive layer 205, and by then detecting changes in the corner currents resulting from the AC current sinking from a finger (or stylus) contact on the sensor. Controller electronics 110 performing these AC functions are also known as capacitive touchscreen controllers. The present invention

improves linearity in other touchscreen systems employing other types of controller electronics.

Controller electronics 110 and/or host computer 115 may include algorithms for correcting non-linearities in the touchscreen sensor according to the present invention.

- 5 Correction of non-linearities may become important if the touchscreen is designed to consume low power and/or have narrow borders. For such algorithms, "correction coefficients" for non-linear corrections are produced and used for compensating for non-linearities, e.g., as described in WO 97/34273, incorporated herein by reference.

Fig. 5 shows an exploded segmented view of the components of touchscreen 105 in accordance with one preferred embodiment of the present invention. It will be recognized that the thickness, height, or other dimensions of some of the components in some of the drawings has been exaggerated for purposes of illustration. Touchscreen 105 comprises a gradient sheet 195 including a substrate 200 having a uniform resistive layer 205 permanently applied to one surface thereof. Preferably, uniform resistive layer 205 is durable (adherent, chemically stable, etc.). Resistive layer 205 further includes a touch region which is generally illustrated as 206 in Fig. 5.

The geometry of substrate 200 may be planar (as shown in Fig. 5) or may be contoured to match the face of a curved object, such as CRT face 150 of Fig. 4. Substrate 200 can also have any perimeter configuration, e.g., substantially rectangular to match the configuration of a typical video display. Substrate 200 can also have a perimeter configuration which matches the configuration of a circular touch sensor as described in US 4,777,328, incorporated herein by reference. Typically, a substrate 200 constructed from glass will have a resistivity value in excess of about 108 ohms per square. This substrate 200 typically has a thickness of about two to three millimeters.

25 For a substantially transparent touch sensor, substrate 200 may be constructed from glass, plastic, or from other substantially transparent materials. Additionally, resistive layer 205 on substrate 200 should also be substantially transparent (i.e., transmission of at least 60%, and preferably at least 80%). In such instance, resistive layer 205 is typically a semiconducting metal oxide such as ITO.

Alternatively, if the product is to be an opaque sensor, substrate 200 may be glass, acrylic or other rigid plastic, or various types of printed circuit board materials, or a metal having a previously applied insulating layer. Furthermore, various plastic materials for substrate 200 can be utilized in the form of flexible sheets and supported upon a suitable hard surface material. Resistive layer 205 is typically adherently applied by screening a resistive ink or by spraying a resistive paint upon substrate 200. Or, resistive layer 205 may be a volume of conducting sheet such as rubber or plastic. For an opaque sensor, resistive layer 205 may have a sheet resistivity ranging from about 10 to about 10,000 ohms per square and can be applied within a variation of uniformity of about one percent to about twenty-five percent, depending upon the positional accuracy needed.

Typically, resistive layer 205, if it comprises ITO, has an approximately uniform resistivity from about 10 to about 10,000 ohms per square, preferably, from about 100 to about 1,000 ohms per square, and more preferably from about 150 to about 300 ohms per square. Typically, its thickness is less than a wavelength of light.

Resistive layer 205 may be other semiconducting metal oxides such as indium oxide, tantalum oxide, tin oxide, antimony oxide, or a combined layer of, e.g., antimony oxide and tin oxide. Other similar resistive layers which are adherent, chemically stable, and provide a resistance in the range of from about 100 to about 3,000 ohms per square, without excessively reducing the transparency of the sensor, are suitable. In general, nonstoichiometric oxides of metals in Groups III and IV, with metal impurities from adjoining Groups of the Periodic Table of Elements, are suitable.

Substrates having ITO resistive layers are described in more detail in US 4,220,815. Such ITO-coated substrates may be purchased commercially, for example, from Optical Coating Laboratory, Inc. (OCLI) of Santa Rosa, California, and Information Products, Inc. (IPI) of Holland, Michigan.

Continuing to refer to Fig. 5, spaced a small distance above resistive layer 205 is a cover sheet 210, which is typically a flexible film 215 having a conductive coating 220 on its underside. Cover sheet 210 prevents any damage to resistive layer 205. Typically, flexible film 215 has a stiff and durable coating possessing a clear or anti-glare finish. The thickness of flexible film 215 may be, for example, about 0.005 inch (0.125 mm). Flexible

film 215 may be manufactured from a rigid-like plastic (such as polyester or polycarbonate), polyvinylchloride, or an elastomeric material, or any other suitable material.

If the sensor is to be transparent, then conductive coating 220 must also be transparent or substantially so and may be, for example, a deposit of a metal such as gold-nickel or a semiconductor such as an oxide of a metal selected from the group consisting of  
5 tantalum, indium, antimony, and mixtures thereof, with ITO being preferred..

While the embodiment of Fig. 5 utilizes a cover sheet, the present invention is not so limited. For example, any conducting element, such as a conducting stylus (not shown in Fig. 5), can be used as an alternative means for contacting resistive layer 205. This  
10 conducting stylus may be used when resistive layer 205 is sufficiently durable as to withstand damage from such contact. As another alternative, a capacitive or resistive pickup system can be used along with a user's finger or with an appropriate probe.

As further shown in Fig. 5, cover sheet 210 is typically joined to the rest of touch-screen 105 by an adhesive along its associated edges or, optionally, by an insulative adhesive frame 225 or the like. Additionally, an electrode 230 connects conductive coating 220  
15 via lead 235 to an appropriate external circuitry, such as controller circuit 110.

Typically, conductive coating 220 is separated from resistive layer 205 by a plurality of small transparent insulator islands or dots 240, which prevent accidental contact between conductive coating 220 and resistive layer 205, but yet permit contact there-  
20 between by a small applied pressure from a finger or of a small object. These insulator islands are further shown and described in US 4,220,815 and 5,220,136.

With continuing reference to Fig. 5, a resistor chain 245 is spaced along each edge of resistive layer 205 and is used for applying potentials to resistive layer 205 so as to create orthogonal voltage gradients therein. As shown in subsequent figures, resistor chain  
25 245 (composed of conductive regions, insulating regions, and resistive regions) includes discrete resistance units connected in series (see, e.g., resistor chains 245a-245e in Figs. 6-10, respectively). The resistance values of resistor chain 245 depend partly upon the value of the resistivity of the coating which forms part of resistor chain 245. According to a preferred embodiment of the invention, the resistivity of coating 205 can have a value from  
30 about 100 ohms per square to about 1000 ohms per square. However, the resistance values

of resistor chain 245 may vary in accordance with design requirements. There are four resistor chains 245 in the embodiment of Fig. 5 which are more specifically labeled 250, 255, 260, and 265. The ends of each resistor chain 250, 255, 260 or 265 are joined at or near the corners of resistive layer 205, as at corner 270. Each of the corners is provided with an electrical lead, such as electrical leads 275, 280, 285, 290, whereby touchscreen 105 is connected to a conventional controller electronics or circuitry 110 which provides the voltage to resistor chain 245 and which processes information from touchscreen 105.

When touchscreen 105 is pressed, conductive coating 220 makes direct electrical contact with resistive layer 205. For a quasi-DC resistive touchscreen, commonly referred to as a "resistive touchscreen," cover sheet 210 can function as either a voltage sensing probe for sensing the voltage at the contacted area, or as a current injection source. When functioning as a voltage sensing probe, cover sheet 210 serves to sample and to measure the voltage of gradient sheet 195 at the point of contact. When functioning as a current injection source, cover sheet 210 is connected to a current source (provided by controller electronics 110) which injects current into resistive layer 205 of substrate 200 when touchscreen 105 is activated. The electrodes at the corners (e.g., at corner 270) of substrate 200 are connected to controller electronics 110 (as shown in Fig. 5) where current flows to virtual grounds are detected. Controller electronics 110 observes the division of the injected currents between the four corners of substrate 200, and the sum of the currents at the four corners provides a touch detect signal. The sum of the right corner currents, divided by the injected current, represents an X-coordinate measurement. The sum of the top corner currents, divided by the injected current, represents a Y-coordinate measurement. As noted in lines 36-65 of column 4 of US 4,293,734, the measured X- and Y-coordinates are independent of controller electronics 110 read-out scheme (because the same results are achieved if cover sheet 210 functions as a voltage-sensing probe or as a current injection source).

Touch information is in the baseband for the analog signals propagating between touchscreen 105 and controller electronics 110. When touchscreen 105 is excited in the X-coordinate measuring mode, controller electronics 110 will allow several RC time constants (i.e.,  $\tau = RC$ ) to pass before digitizing the analog signals.



Fig. 6 shows another embodiment 195a of the gradient sheet, having a central uniform resistive layer 205 (shown in Fig. 5) of, for example, two hundred ohms per square. Positioned along each edge of the surface of gradient sheet 195a is resistor chain 245a formed of a series of overlapping conductive strips 400. Using these strips 400 and the resistivity of resistive layer 205, the specific resistance of resistor chain 245a can be tailored for a particular application and distribution of voltages along the edges of gradient sheet 195a. Typically, conductive strips 400 are physically attached to resistive surface 205 by depositing a conductive material, e.g., silver, in the appropriate pattern. A conductive corner tab (not shown) applies a voltage to the end of resistor chain 245a, and a conductive lead (not shown) typically connects the conductive corner tab to a tab (not shown) at another location of gradient sheet 195a. The conductive corner tab is connected to appropriate external circuitry (as within circuitry 110) for supplying the voltage source. A portion of an overlapping conductive strip 400 is in a generally spaced relationship with at least a portion of another overlapping conductive strip 400 to produce an overlapped resistive region 402. Thus, at least one pair of spaced conductive strips 400 provide generally opposed boundaries for defining overlapped resistive region 402 between spaced conductive strips 400.

At least a portion of one of strips 400 is parallel or generally parallel to at least a portion of another strip 400. Additionally, strips 400 are positioned on and electrically connected to resistive layer 205 (shown generally in Fig. 5) of gradient sheet 195a.

A conductive lead 405 connects a T-shaped electrode 410 to an overlapping conductive strip 400. Conductive leads 405, along with resistor chain 245a, provide the appropriate reference voltage to T-shaped electrodes 410. The length and spacing of T-shaped electrodes 410 are chosen to compensate for any cumulative voltage drop along resistor chain 245a, portion which is perpendicular to the current flow on resistive layer 205. Stated alternatively, the spacings and effective lengths of T-shaped electrodes 410 are selected to produce a voltage gradient at each T-shaped electrode to compensate for any voltage drop that occurs along resistor chain 245a. Overlapping conductive strips 400, conductive leads 405, and T-shaped electrodes 410 each have, e.g., a width of about 0.5 mm, and all are formed, e.g., by screen printing and curing silver frit in the desired pattern.

As shown in Fig. 6, insulation regions 300 are formed adjacent to overlapping conductive strips 400, conductive leads 405, and T-shaped electrodes 410. An insulating region 300 extends into and terminates in an overlapped resistive region 402 from outside of overlapped resistive region 402. Insulation region 300 has, for example, a width of about 50  $\mu\text{m}$ . According to this particular embodiment of the present invention, insulating region 300 includes an insulating region portion 415 which extends into and terminates in an overlapped resistive region 402, and an insulating region portion 420 which is outside overlapped resistive region 402. Overlapped resistive region 402 is generally a continuous section of resistive layer 205. Insulating region 300 (shown in Figs. 6-10) may vary in shape or configuration. For example, insulating regions 300 may be formed as continuous lines (as shown in Fig. 6), dashed or discontinuous lines, spacer dots, and as other suitable shapes and sizes sufficient to control current flow on resistive layer 205.

Overlapped resistor length  $L$ , as indicated by double-headed arrows 425, is defined by the distance separating an insulating region portion 415 from another insulating region portion 415 in overlapped resistive region 402. Arrow 425 thus represents the length of a resistive region 402 which permits current flow therethrough. The separation distance or gap  $G$  between overlapping conductive strips 400 is further indicated by double-headed arrows 430. Accordingly, the resistance between two overlapping conductive strips 400 is directly proportional to the resistivity of coating 205 (see Fig. 5) and is approximated by Equation (1).

$$(1) \quad R \approx \rho G / L$$

In Equation (1),  $\rho$  represents the resistivity (ohms per square) of resistive layer 205 (see Fig. 5) of gradient sheet 195a. Equation (1) is an approximation, since the actual resistance may vary due to contact resistance and due to fringing effects at the ends of an overlapped resistive region 402. A direct measurement of resistance  $R$  of each overlap structure can be taken by placing the leads of an ohmmeter between consecutive conductive leads 405. The width of, e.g. conductive lead 405, may be widened to, e.g. about 2.0 mm, in order to facilitate its role as a test point.

The geometry of insulating region portions 415 can be varied to set the value of  $L$ . From Equation (1),  $L$  can be varied to adjust resistance  $R$ . If a direct resistance measure-

ment or if the linearity data (from linearity testing of gradient sheet 195a) indicates that R is too small, then laser ablation processes (for example) can be used to reduce length L, thereby increasing the value of R. By varying L, the current flow can be controlled in the overlapped resistive region. Other methods, such as numerically-controlled scribing, can be used to shape insulation regions 300 and insulation region portions 415.

Conversely, if a smaller value of R is desired, then a larger value of L is used to define the geometry of portions 415. For example and as best shown in Fig. 6A, portions 415 have been set to not extend extensively into overlapped resistive region 402. Thus, L, as represented by double-headed arrow 425', may extend any desired fraction of the distance between overlapped boundaries 432,432 which defines the outer boundaries of overlapped resistive region 402. As shown above in Equation (1), R is adjustable by altering the geometry of insulative regions 300. Thus, overlapping resistor chain 245a becomes, in effect, a chain of adjustable potentiometers.

In addition and as shown best shown in Figs. 6 and 6A, the resistance between a node in resistor chain 245a and touch region 206 of resistive layer 205 can be likewise varied by adjusting distance 433 through alteration of the geometry of insulative regions 300. Double-headed arrow 433 thus represents a resistive section which permits current flow therethrough.

Figs. 6B and 6C illustrate various amendments of insulating region 300, as seen in a partial vertical sectional view looking in direction of the arrows and along the plane of line 315-315 in Fig. 6. An insulating region 300 may be formed in various ways. Referring initially to Fig. 6B, insulating region 300 is formed by creating a channel or void 350a in resistive layer 205 and above substrate 200, such that a portion of substrate 200 is exposed. Channel 350a forms an insulating zone which interrupts current flow through resistive layer 205. Preferably, channel 350a may be formed by removing or altering portions of resistive layer 205 with a scribe, more preferably with a laser or any other suitable like implement. For example, low-powered, lasers may be used for control-cutting resistive layer 205 to form channel 350a therein. Laser ablation of ITO-coated substrate are performed by, for example, Optical Coating Laboratory, Inc.

Portions of resistive layer 205 may be removed or altered by other suitable methods, such as chemical etching, photo-etching, chemical or acid deposition, masking, mechanical etching, welding, high-photon etching, thermal etching, or other suitable etching methods. Additionally, the removal of portions of resistive layer 205 typically requires removal of  
5 resistive layer 205 in multiple locations of gradient sheet 195a (see Fig. 6). The process of removal of resistive layer 205 may be iterated if necessary.

Channel 350a may have, for example, a width of about 50  $\mu\text{m}$ , as represented by double-headed arrows 352. The height of channel 350a is represented by double-headed arrows 354 and is about equal to the thickness of resistive layer 205. For example, channel  
10 350a may have a height of less than a wavelength of light. The shallowness of channel depth 354 supports low cost processes for removal of resistive layer 205.

As shown in Fig. 6C, the channel in resistive layer 205 may be formed with different configurations, such as channel 350b. Additionally, in Figs. 6B and 6C the insulative characteristics of insulating region 300 is partly dictated by the extent of the  
15 conductivity of substrate 200. Based on the teachings of the present invention, it also follows that a dielectric or non-conducting insulative material, such as glass, can be formed in the channel of resistive layer 205. Other types of solid, non-conductive materials which can be used as insulative material include, but are not limited to, porcelains, mica, magnesia, alumina, aluminum silicate, various high polymers (e.g., epoxies, polyethylene,  
20 polystyrene, PVC, phenolics, etc.) cellulosic materials, cellular rubber, nylon, and silicon resins. These materials may be used alone or in combination with other insulators.

Fig. 7 shows another embodiment of the gradient sheet, generally illustrated as 195b. A series of conductive strips 500 forms resistor chain 245b. Insulating region 300 includes an insulating region portion 505 which extends into an overlapped resistive region  
25 510. Preferably, insulating regions 300 also include an upper insulating region segment 515 and T-shaped insulating segments 517, all of which are outside of overlapped resistive regions 510. Overlapped resistor length (L), as indicated by double-headed arrows 520 is defined by the distance separating an insulating region portion 505 in overlapped resistive region 510 from another insulating region portion 505 in overlapped resistive region 510.  
30 Double-headed arrow 520 thus represents a resistive section which permits current flow

therethrough. The separation distance or gap ) between overlapping conductive strips 500 is indicated by double-headed arrows 525. Accordingly, the effective resistance value between two overlapping conductive strips 500 is also approximated by Equation (1). Additionally, the resistances between nodes in resistor chain 245b and touch region 206 of  
5 resistive layer 205 can be adjusted by setting a resistive section defined by double-headed arrows 527.

Gradient sheet 195b, as shown in Fig. 7, may be applicable for predictably non-linear, low-power sensors with narrow borders. A predictably non-linear sensor is attained by use of controller electronics 110 or driver software which would apply fixed linearity  
10 correction coefficients to compensate a reproducible non-linearity. Such driver software is implemented based on, for example, in WO 97/34273. Preferably, distances 520 and 527 are adjusted to limit the number of variable non-linear correction coefficients required.

Fig. 8 shows another embodiment of the gradient sheet, generally illustrated as 195c. A series of conductive strips 550 and insulating regions 555 and 560, and resistive  
15 layer 205 form resistor chain 245c. Insulating region 300 includes an upper insulating section 555, T-shaped insulating sections 560, and corner insulative sections 565. A portion of a conductive strip 550 is in a generally spaced relationship with at least a portion of another conductive strip 550 to produce an overlapped resistive region 570. Upper insulating section 555 includes insulating subsections 575 which extend into overlapped resistive  
20 region 570. Similarly, a T-shaped insulating section 560 includes an insulating subsection 580, while a corner insulating section 565 includes an insulating subsection 585, wherein insulating subsections 580 and 585 extend into a resistive region 570. The resistances of resistor chain 245c can be adjusted by setting values of lengths L1 and L2, as represented by double-headed arrows 590 and 595, respectively. Length L1 is set by adjusting the geo-  
25 metry of insulative subsections 575 and 580 in overlapped resistive regions 570. Length L2 is set by adjusting the geometry of T-shaped sections 560. The geometry of subsections 575 and 580 and of T-shaped sections 560 may be adjusted by, for example, laser ablation.

Fig. 9 shows yet another embodiment of the gradient sheet, generally as 195d. A series of conductive strips 600 and overlapped resistive region 605 form resistor chain  
30 245d. Insulating regions 300 include a T-shaped insulating region having an insulating

subsection 615. Insulating subsection 615 communicates with another insulating subsection 620 which is generally normal thereto and which terminates in and contacts two contiguous opposed overlapping conductive strips 600 within overlapped resistive region 605. A portion of T-shaped insulating region 610 disposed outside of overlapped resistive region 605 includes an insulating segment 625 which terminates in and makes contact with the same two opposed contiguous overlapping conductive strips 600 outside of overlapped resistive region 605.

Insulating regions 300 further include an insulating segment 630 which also includes an insulating segment 635 terminating in another insulating segment 640. Insulating segments 635 and 640 are typically disposed in overlapped resistive regions 605. Additionally, insulating segment 640 terminates in two opposed contiguous overlapping conductive strips 600. The resistances of resistor chain 245d are adjusted by setting the lengths of resistive section widths represented by double headed arrows 645 and 650. Because resistive region 605 is rectangular in shape, Equation (1) more accurately predicts the resistance of region 605, and hence simplifies the adjustment of this resistance.

Note that the resistance of resistive region 605 is independent of any moderate registration offsets between conductive regions 600 and insulating regions 300.

Fig. 10 is a top plan view of another embodiment of the Fig. 9 gradient sheet, generally illustrated as 195e, and having T-shaped insulating region 610 disposed outside of overlapped resistive region 605. For gradient sheet 195e, insulating segment 625 forms an angle  $\theta$  with a conductive strip 600. The angle  $\theta$  value may differ for each T-shaped insulating segment 610 in gradient sheet 195e of the same touchscreen sensor. For example, sub-segment 627 of insulating segment 625 may be rotated in the direction of arrow 627a to increase the value of the angle  $\theta$ . Sub-segment 627 may be rotated in the direction of arrow 627b to decrease the value of the angle  $\theta$ .

The resistances of resistor chain 245e can be adjusted further by setting the overlapped resistor spacing (as indicated by double-headed arrows 645), T-shaped insulating segment 610 spacing (as indicated by double-headed arrows 650), and by the angles  $\theta$  formed by insulating segment 625. The resistances between touch region 206 and resistor chain 245e will vary as a function of manufacturing variations in the offset between

conductive electrodes 600 and insulative region 300. By varying the values of the angle  $\theta$ , the rate which this effective resistance changes (as a function of the offset magnitude) is altered. Thus, adjustment of the angle  $\theta$  provides a design degree of freedom for reducing sensor non-linearities caused by manufacturing offset variations.

5 Fig. 11 shows a top level view of gradient sheet 195d of Fig. 9. The pattern of resistor chain 245d of Figs. 9 and 11 simplifies the calculation of the resistances of resistor chain 245d, minimizes the effects of manufacturing registration offsets (manufacturing variations), and facilitates a simplified iterative feedback loop which corrects the resistance values in order to compensate for material variations and/or process variations.

10 Referring now to Fig. 12, a capacitive (AC resistive) embodiment of a touchscreen, generally illustrated as 700, is shown according to the present invention. A substrate 705 (typically glass or plastic) includes a resistive layer 710 (typically ITO or ATO). Conductive electrodes 715 are provided and electrically connect to resistive layer 710. Insulating regions 720 may be formed by removing portions of resistive layer 710 by laser  
15 ablation or other suitable methods discussed above. A dielectric layer 725 is formed directly on resistive layer 710, while a conductive (resistive) coating 730 (e.g., ITO or ATO) may be applied to the bottom of substrate 705 as a guard electrode.

When the four corners electrodes (not shown) of substrate 705 are driven by an AC signal, a finger 735 "grounded" to a human body functions as a current sink, thereby providing a current path from the corner electrodes via capacitive coupling to grounded finger  
20 735. This mode of operation is, in effect, a "current sinking mode" wherein the four substrate corner electrodes are excited by an equal voltage level. When grounded finger 735 is placed in mechanical contact with dielectric layer 725, grounded finger 735 is capacitively coupled to resistive layer 710, and changes in the AC currents in the four  
25 substrate corner electrodes are then observed for determining the location of the touch of grounded finger 735. Dielectric layer 725 insures that grounded finger 735 is in close proximity with resistive layer 710 without DC contact. For manufacturing process control, touchscreen linearity can first be tested in a quasi-DC resistive touchscreen mode, and insulative regions 720 are then formed or adjusted accordingly before dielectric layer 725 is  
30 formed. Conductive coating 730 serves two functions. First, it can act as an electronic

shield between resistive layer 725 and possible electronic noise sources located adjacent to the touchscreen, such as the display device. Second, if conductive coating 730 is driven by the same AC driving signals which are applied to the four corner electrodes, then the current sinking effects of the stray capacitance between resistive layer 710 and the surrounding environment are greatly reduced.

Continuing to refer to the drawings, substrate 200 is provided with resistive layer 205 which converts physical position information thereon into electrical signals. A dimension is then determined for a length of a resistive section which is to be located in resistive layer 205. In Fig. 6, the resistive sections (as defined by distances 425 and 433) permit the flow of current therethrough from and through resistor chain 245a. In Fig. 7, the resistive sections (as defined by distances 520 and 527) permit the flow of current there-through from and through resistor chain 245b. In Fig. 8, the resistive sections (as defined by distances 590 and 595) permit the flow of current therethrough from and through resistor chain 245c. In Figs. 9 and 10, the resistive sections (as defined by distances 645 and 650) permit the flow of current therethrough from and through resistor chain 245d.

The dimension for a length of a resistive section is determined by electrical excitation in the resistive layer. Electrical excitation may be provided, for example, by excitation voltages or by current injection. More specifically, during the linearity testing stage, the electrical behavior of gradient sheet 195 is tested by observing the electrical field patterns thereon. Testing of linearity, or more generally, measurement of discrepancies between desired and observed voltage gradients, during manufacture is key to realizing the advantages of the electrode patterns (i.e., resistor chains 245a-245e in Figs. 6-10, respectively). Linearity testing may, e.g., involve exciting the four corner electrodes at corners 270 (see Fig. 5) with "X", and then "Y", excitation voltages. For each type of excitation voltages, voltages at a rectangular grid of points, e.g. 6 by 8, are measured with a volt meter probe. Thus, with testing of this type, the electrode designs discussed above provide an ability to easily and rapidly adapt to manufacturing variations and speed design optimization.

Consider a batch process, in particular, what happens after a lot of glass substrate has been coated with ITO and provided with the silver-frit pattern of conductive electrodes. Using the nominal design geometry for the regions of removed ITO, a small sampling from



the lot, e.g. 3 substrate units, is further processed and tested for linearity. In Fig. 6, for example, the length L may have a first initial value prior to linearity testing. During linearity testing, the measured discrepancies in the voltage gradients are then used to determine desired changes to the resistance values of the resistor elements of the border electrode pattern. The geometry of the removed ITO regions is then redesigned to implement the desired changes in resistance values of the resistor chains (e.g., resistor chains 245a-245e). The resistance values of a resistor chain 245a is tuned, such that, e.g., a uniform voltage gradient can be excited on resistive layer 205 (see Fig. 5), i.e., linearity is achieved throughout resistive layer 205. Thus, according to the present invention, the desired linearity is achieved by adjusting the resistances of resistive region 402 of resistor chain 245a in gradient sheet 195a. The modified design for the geometry of the removed ITO is then used to process the remaining substrate units of the lot.

The above electrode patterns also provide similar advantages for continuous processes. By periodically testing linearity of samples from a continuous production line, the geometry of the removed-ITO regions can track drifts in the manufacturing process.

A key observation here is that programmable low-cost manufacturing processes exist for creating regions of removed ITO (insulation regions 300). These processes include, but are not limited to, laser ablation or scribing, for which a change in design geometry requires only reprogramming of numerically controlled manufacturing equipment. In contrast, the silver-frit electrode pattern of resistor chains 245a-245e is most cost-effectively applied using a screen printing process that does not support fast modifications of silver-frit electrode geometry in response to manufacturing variations.

Algorithms used in the adaptive process of creating insulation regions 300 require quantitative information on the correlations between voltage gradient discrepancies and changes in the resistance values from alternations in removed-ITO geometry of insulation regions 300. These correlations may be determined by computer simulations that numerically solve Poisson's equation for the boundary conditions corresponding to various modifications of the electrode design. Alternately, these correlations may be determined experimentally by observing voltage gradient discrepancies induced by alternations in removed-ITO geometry of insulation regions 300.

Such adaptive processes can compensate for batch-to-batch variations or drift in the uniformity of the ITO coating process, line width variations and other variations in the silver-frit electrode process, and other sources of variation in the manufacturing processes, thereby reducing manufacturing costs.

5 Furthermore, the easily optimized designs of the invention (including the electrode designs above) may also reduce the time to market for new products. Additionally, the invention permits cost-effective production of sensors originating from "last-minute" or customized orders. This contrasts with prior art designs for which non-linearities from the electrode pattern design, perhaps due to quantitative errors in process-dependent design  
10 parameters, are difficult to correct.

Reference is now made to Fig. 10, by way of example, to describe the adjustment of the dimension of a length of the resistive sections (as represented by distances 645 and/or 650). First insulating region 610 is formed in resistive layer 205 (see Fig. 5), while second insulating region 630 is formed and is spaced at a distance 645 from first insulating region  
15 610 such that distance 645 defines the length of a resistive section through which current may conduct. First insulating region 610 (or second insulating region 630) extends to an overlapped region 605 from a portion of resistive layer 205 (see Fig. 5) which is outside overlapped region 605.

If the length of the resistive section, as best represented by distance 645, is to be  
20 adjusted, then first insulating region 610 may be extended further into overlapped region 605. This would decrease distance 645 and thus increase resistances of resistor chain 245e. Alternatively, first insulating region 610 may extend only slightly into a portion of resistive layer 205 (see Fig. 5) which is inside overlapped region 605. Under this alternative, distance 645 increases and the resistance of resistor chain 245e decreases.

25 In Fig. 10, first insulating region 610 is also spaced at a distance 650 from an adjacent first insulating region 610. Distance 650 can be adjusted to further set the value of the resistance between nodes of resistor chain 245e and touch region 206 of resistive layer 205. For example, by decreasing distance 650, this resistance increases. By increasing distance 650, this resistance decreases.

First insulating region 610 and second insulating region 630 (of insulation region 300) may be formed by etching a channel 350a or 350b (see Figs. 6B and 6C) in resistive layer 205 (see Figs. 6B and 6C again). Preferably, the etching of channel 350a or 350b is performed by laser etching or ablation. Alternatively, channel 350a or 350b (see Figs. 6B and 6C again) may be formed by numerically-controlled scribing of resistive layer 205 (see Figs. 6B and 6C again).

The position touch sensor and method according to the present invention is applicable to resistive touchscreen (quasi-DC resistive touchscreens) 105, as shown in Fig. 5, and to capacitive touchscreens (AC resistive touchscreens) 700, as shown in Fig. 12.

10 The position touch sensor and method according to the present invention make possible the following advantages. The invention permits partial compensation for manufacturing variations in the ITO coating process, and thus ITO manufacturing tolerances can be relaxed, reducing manufacturing costs. Of interest to low-power touch system design, higher resistivity values tend to have larger manufacturing variations. Such variations can be better tolerated using the present invention. Production of ITO coatings with higher resistivity values are possible while maintaining acceptable linearity performance. ITO coatings which have higher resistivity values are desirable in low-power touch sensors which may be applicable to lap-top/notebook computers and to PDAs.

20 In addition, the present invention decreases yield loss and delays in manufacturing, since resistor chains (245a to 245e) can be quickly tuned to match the characteristics of a particular ITO coating run during the manufacturing process.

25 Although only certain specific embodiments are described herein, it will be recognized by persons skilled in the art that the teachings herein permit the fabrication of other devices which perform as described above. Thus, while the present invention has been described herein with reference to particular embodiments, a latitude of modification, various changes and substitutions are intended in the foregoing disclosure, and it will be appreciated that in some instances some features of the invention will be employed without a corresponding use of other features without departing from the scope of the invention.

## CLAIMS

What is claimed is:

1. A position touch sensor comprising a resistive surface having resistive perimeter  
5 edges; at least one pair of electrodes disposed on, and electrically connected to, said  
resistive surface and including at least one pair of spaced electrode segments to provide  
generally opposed boundaries for defining an overlapped resistive region between the  
spaced electrode segments; and said resistive surface having at least one insulating region  
10 commencing from a resistive point in said resistive surface exterior to said overlapped  
resistive region and terminating in said overlapped resistive region.
2. The position touch sensor of Claim 1 wherein said insulating region comprises a  
channel in said resistive surface.
- 15 3. The position touch sensor of Claim 1 wherein said electrode segments are generally  
parallel.
4. The position touch sensor of Claim 1 wherein said resistive surface has a selected  
substantially uniform resistivity.
- 20 5. The position touch sensor of Claim 1 wherein said resistive surface includes a  
deposited oxide of a metal selected from the group consisting of tantalum, indium, tin,  
antimony, and mixtures thereof.
- 25 6. The position touch sensor of Claim 1 wherein said at least one insulating region  
comprises a channel in said resistive surface formed by the removal of a selected portion of  
the resistive surface.
7. The position touch sensor of Claim 1 wherein said at least one insulating segment  
30 comprises a first insulating segment terminating in a second insulating segment.

8. The position touch sensor of Claim 7 wherein said at least one insulating region additionally comprises a third insulating segment communicating with said second insulating segment exterior to the overlapped resistive region and terminating in said  
5 second electrode segment.

9. A method of modifying the resistance characteristics of a resistive layer between a pair of parallel electrode segments of a position touch sensor comprising the steps of:

a) providing a position touch sensor comprising a substrate having adherently  
10 deposited thereon a resistive layer including a resistive portion, and at least one pair of generally parallel spaced electrode segments positioned on, and electrically connected to, the resistive layer and including an overlapped resistive region between the generally parallel spaced electrode segments and integrally contained within the resistive layer such that said overlapped resistive region includes said resistive portion with said overlapped  
15 resistive region indiscreetly merging with an external resistive region outside of the overlapped resistive region and integrally contained within the resistive layer such that said external resistive region includes said resistive portion; and  
b) altering said resistive portion of the overlapped resistive region and of the  
20 external resistive region.

20

10. The method of Claim 9 wherein said altering step (b) comprises etching an insulating channel in said overlapped resistive region and in said external resistive region wherein said insulating channel extends from a resistive point in said external resistive region to a resistive point in said overlapped resistive region.

25

11. The method of Claim 10 wherein said etching comprises laser etching said insulating channel.

12. The method of Claim 9 wherein said altering step (b) comprises scribing an  
30 insulating channel in said overlapped resistive region and in said external resistive region

wherein said insulating channel extends from a resistive point in said external resistive region to a resistive point in said overlapped resistive region.

13. An impedance surface for converting physical position information on the  
5 impedance surface to electrical signals comprising an impedance surface; a first electrode including a first electrode segment and disposed on, and electrically engaged to, said impedance surface; a second electrode disposed on, and electrically engaged to, said impedance surface and including a second electrode segment generally parallel to said first electrode segment of said first electrode and having an overlapped impedance region in  
10 said insulating surface between said generally parallel first electrode segment and second electrode segment; said impedance surface including at least one insulating segment extending into and terminating in said overlapped impedance region from an impedance region of said impedance surface outside of said overlapped impedance region.
- 15 14. A method for controlling the flow of current through a resistive layer for converting physical position information on the resistive layer into electrical signals comprising the steps of:
- a) providing a resistive layer for converting physical position information thereon into electrical signals;
  - 20 b) determining through the use of electrical excitation in the resistive layer a dimension of a length of a generally continuous resistive section which is to be located in the resistive layer of step (a);
  - c) disposing a first insulating region in the resistive layer of step (a) to form a first boundary of the generally continuous resistive section; and
  - 25 d) disposing, at a distance from the first insulating region essentially equaling the dimension of step (b), a second insulating region in the resistive layer of step (a) to form a second boundary of the generally continuous resistive section such that current may be conducted through the generally continuous resistive section between the first insulating region and the second insulating region.

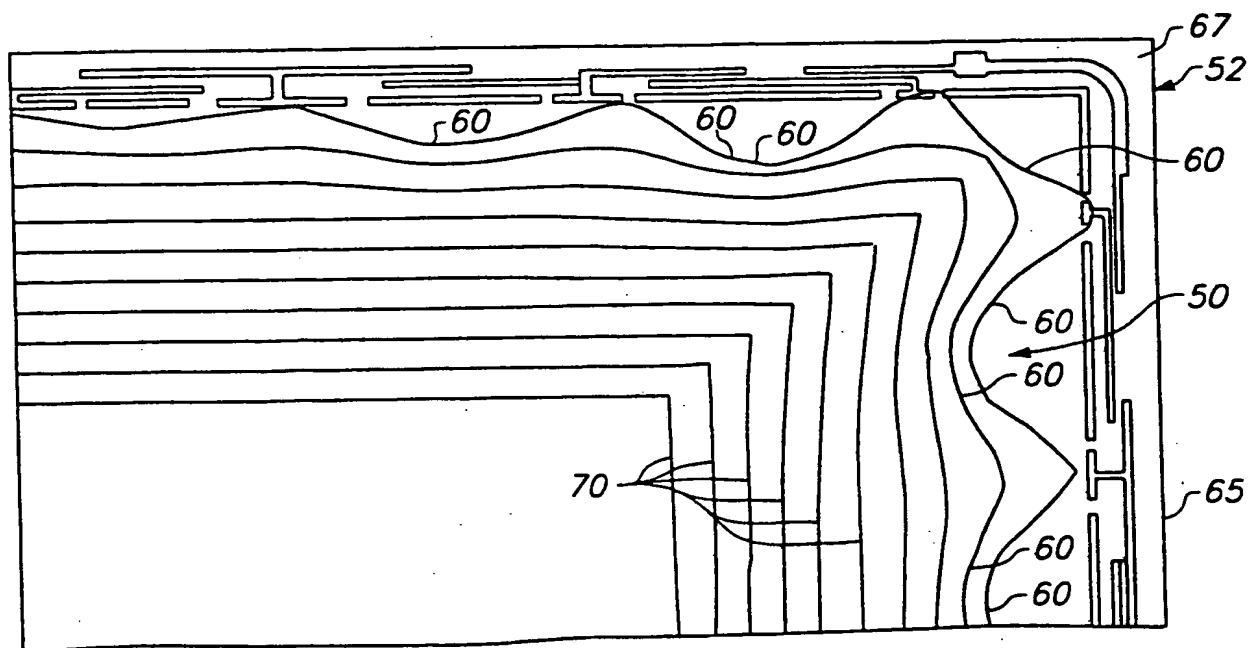
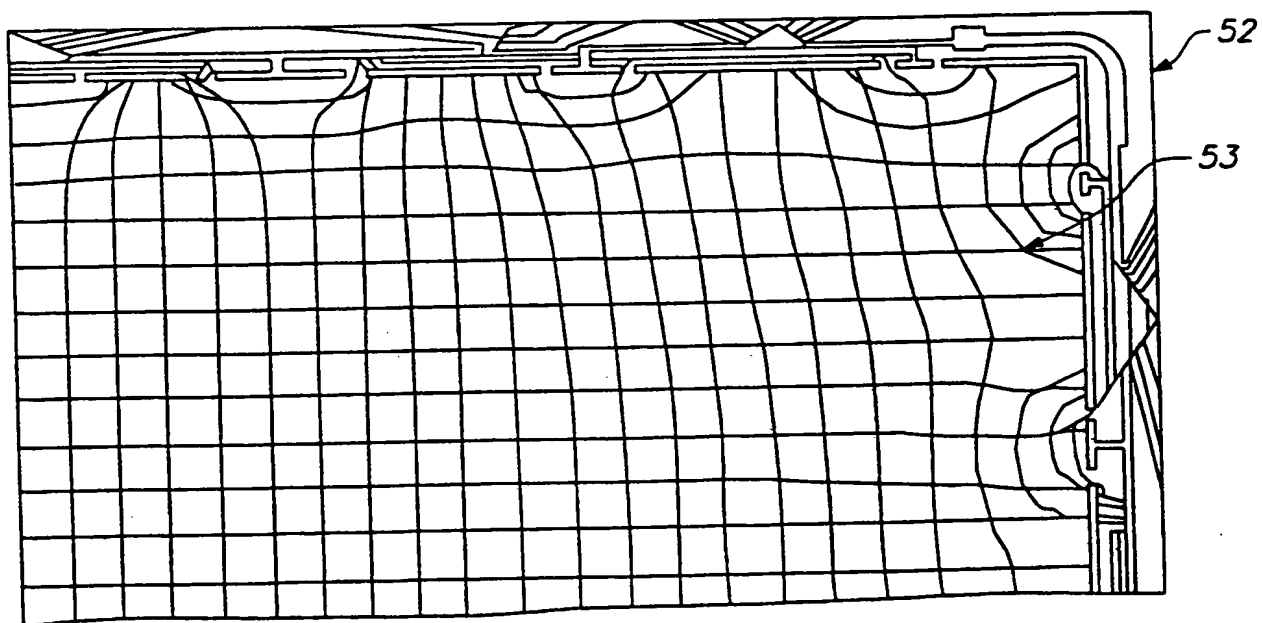
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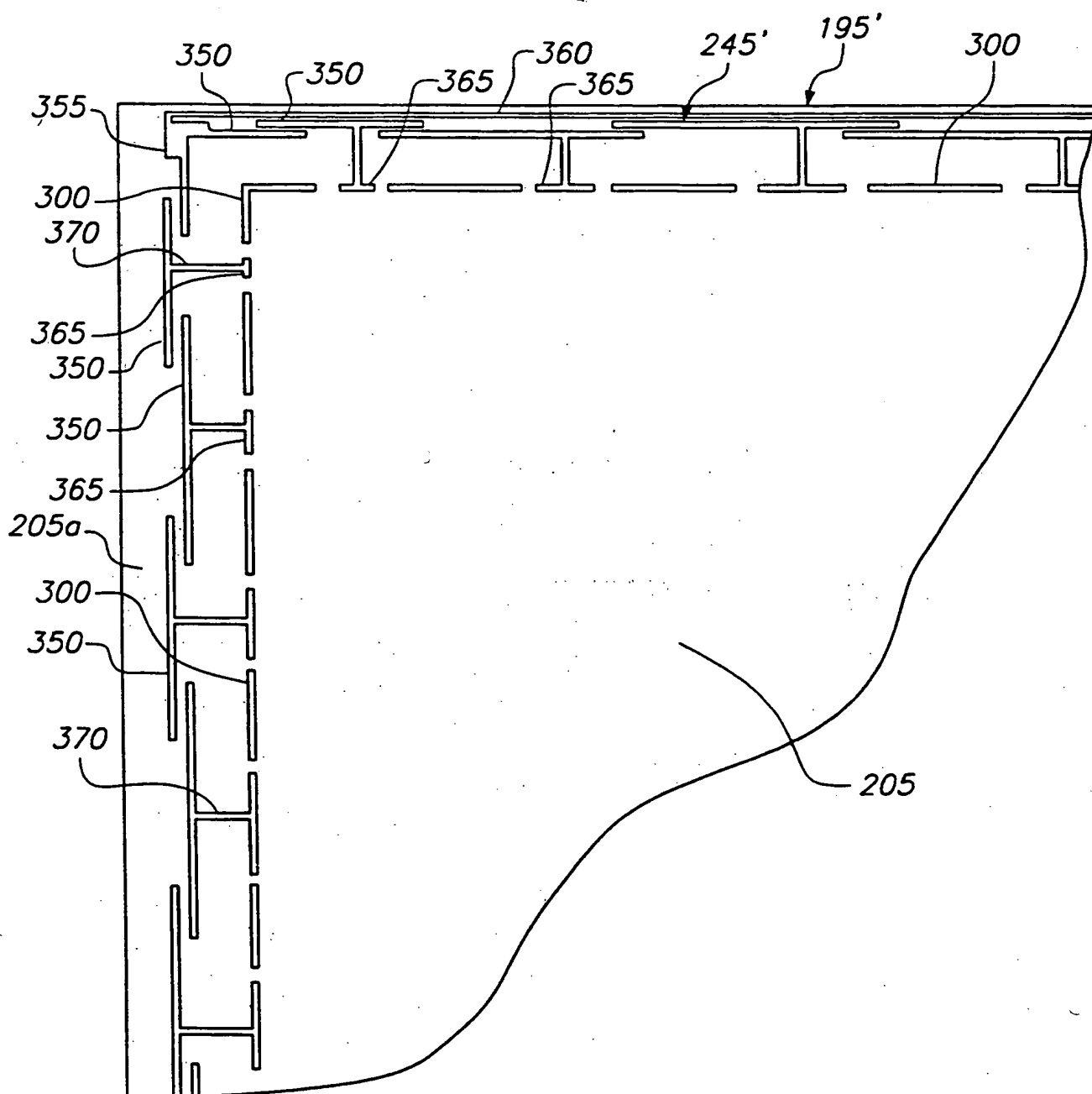
15. The method of Claim 14 additionally comprising providing a pair of generally parallel electrodes engaged to said resistive layer to produce an overlapped resistive region in said resistive layer between said pair of generally parallel electrodes.
- 5 16. The method of Claim 15 wherein said disposing step (c) includes disposing said first insulating region in said overlapped resistive region and said disposing step (d) includes disposing said second insulating region in said overlapped resistive region such that said generally continuous resistive section is located in said overlapped resistive region.
- 10 17. The method of Claim 16 additionally comprising extending said first insulating region in the generally continuous resistive layer of step (c) towards said second insulating region to decrease the dimension of the length of the generally continuous resistive section of step (b) and to increase the resistance of said generally continuous resistive section.
- 15 18. The method of Claim 16 additionally comprising extending said first insulating region around an end of one of said pair of generally parallel electrodes.
19. The method of Claim 14 additionally comprising providing a plurality of generally aligned and spaced electrodes engaged to said resistive layer with a respective end of any  
20 two contiguous electrodes being separated by a resistive region.
20. The method of Claim 19 wherein said disposing step (c) includes disposing said first insulating region in said resistive region and said disposing step (d) includes disposing said second insulating region in said resistive region such that said generally continuous  
25 resistive section is located in said resistive region.
21. A method for reducing manufacturing variations in the curvature of equipotential lines in a touch sensor, comprising the steps of:
- a) providing a substrate having throughout said substrate a first resistivity  
30 value;

- b) disposing a first layer on said substrate of step (a), said first layer having throughout said first layer a substantially uniform second resistivity value less than said first resistivity value throughout said substrate of step (a);
- 5 c) disposing a second layer on said first layer of step (b), said second layer having throughout said second layer a third resistivity value less than said second resistivity value throughout said first layer of step (b), said second layer defining a first layer region which is in proximity with said second layer and is non-contiguous with said second layer, said second layer including a plurality of conductive elements, at least one pair of said
- 10 conductive elements defining an overlapped region which forms a portion of said first layer region;
- d) altering said first layer region to control the flow of current through said first layer.

\* \* \* \* \*

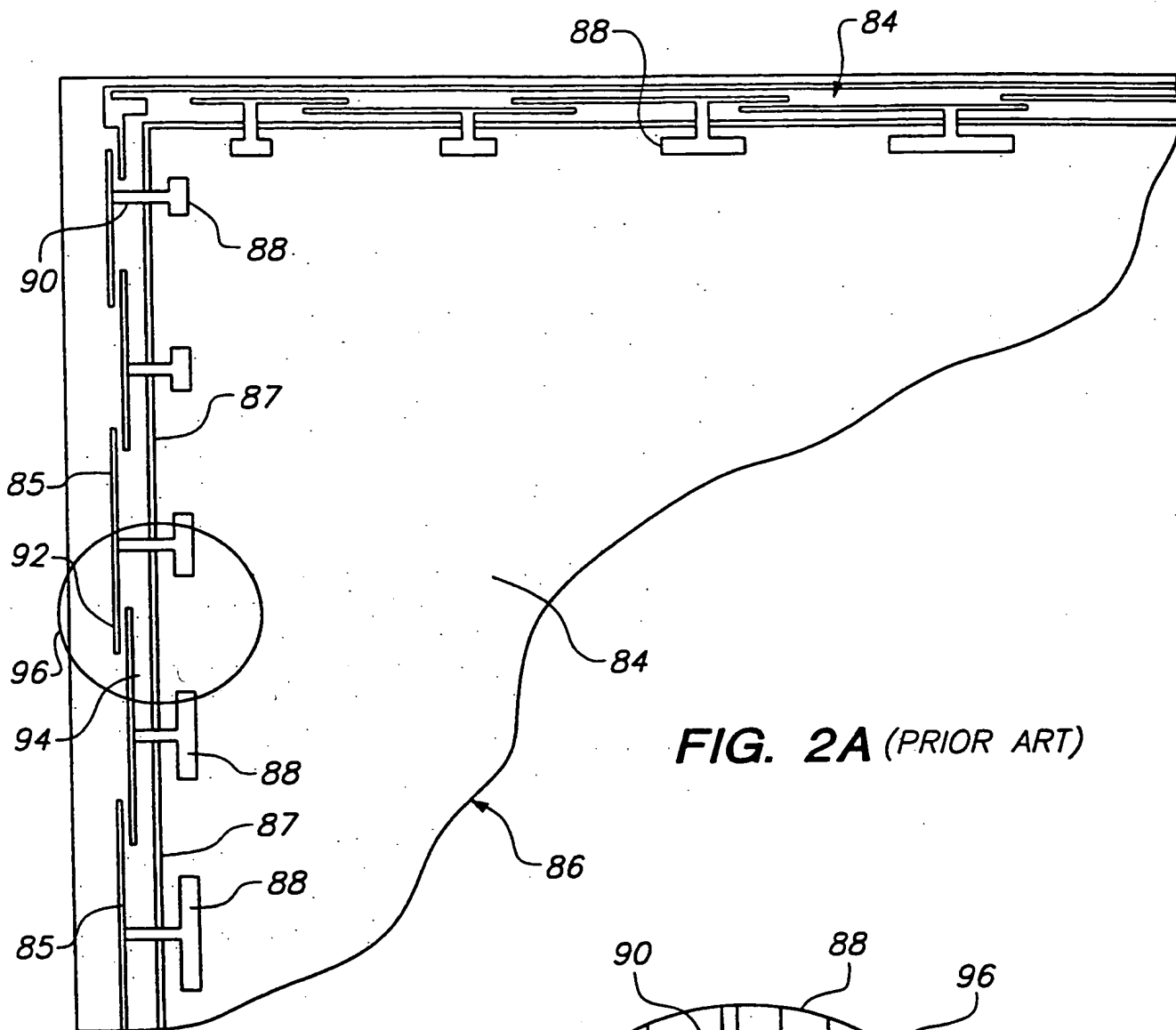


**FIG. 1A** (PRIOR ART)**FIG. 1B** (PRIOR ART)

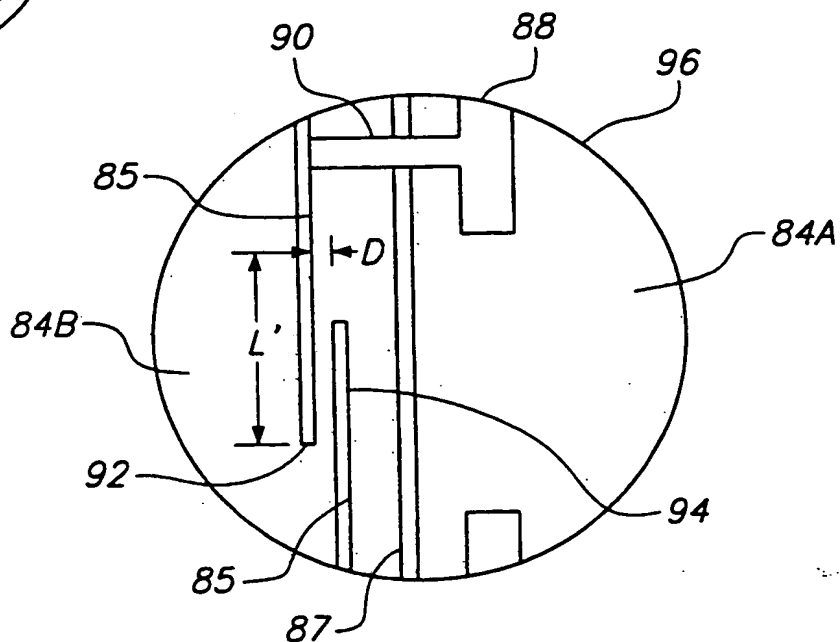


**FIG. 1C (PRIOR ART)**

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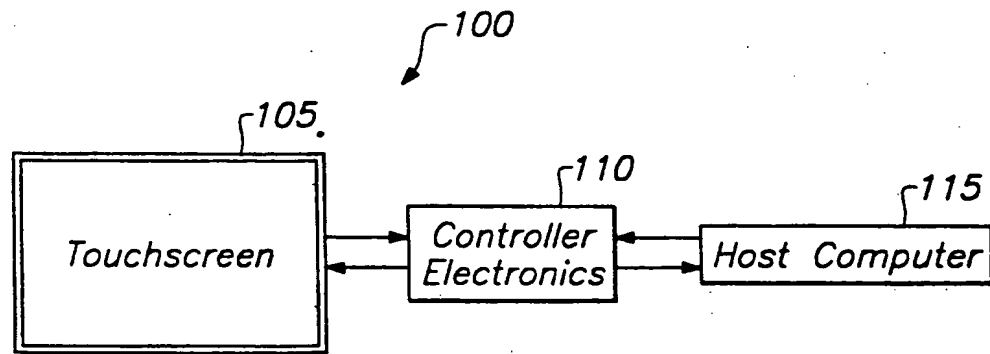
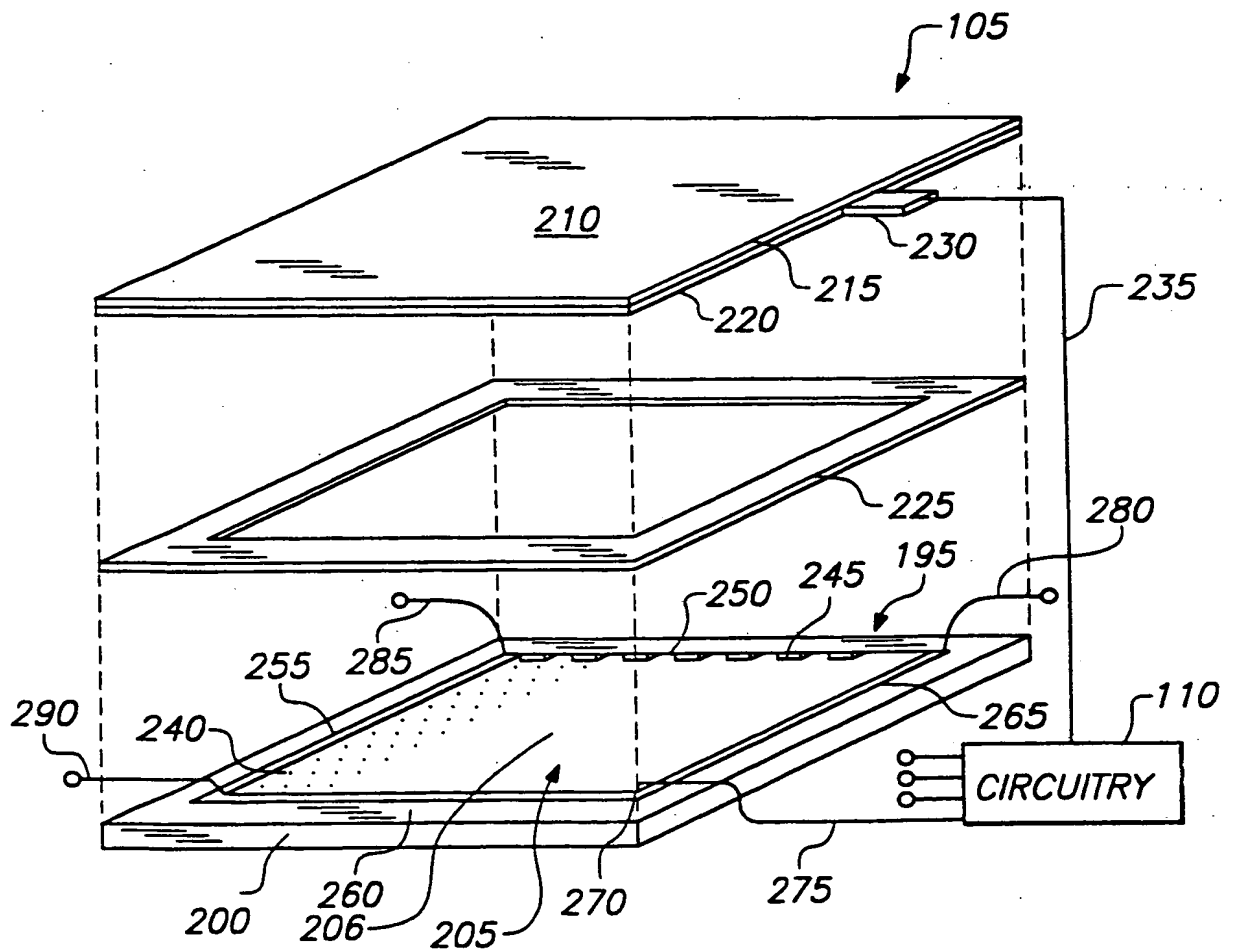


**FIG. 2A (PRIOR ART)**



**FIG. 2B (PRIOR ART)**

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**FIG. 3****FIG. 5**

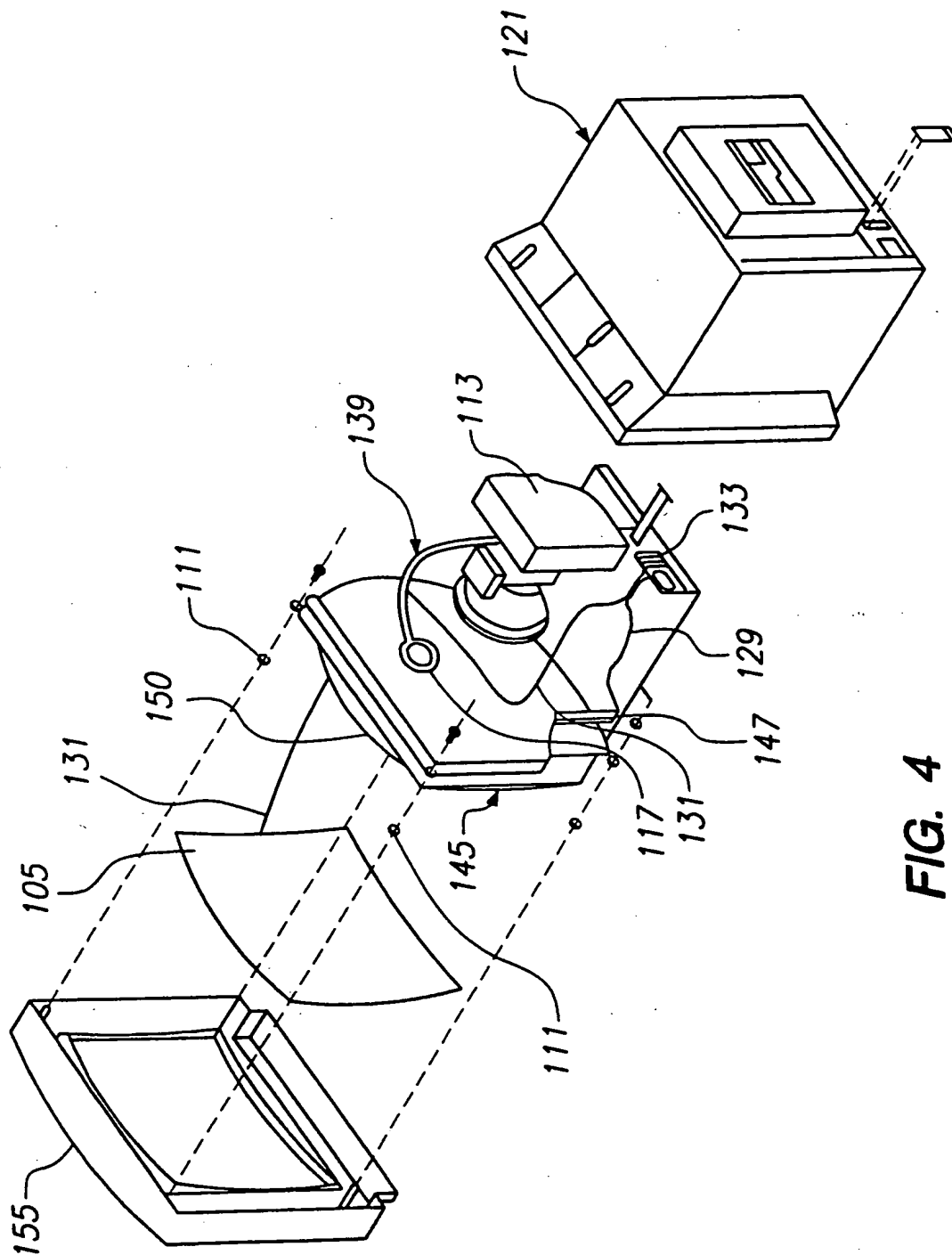
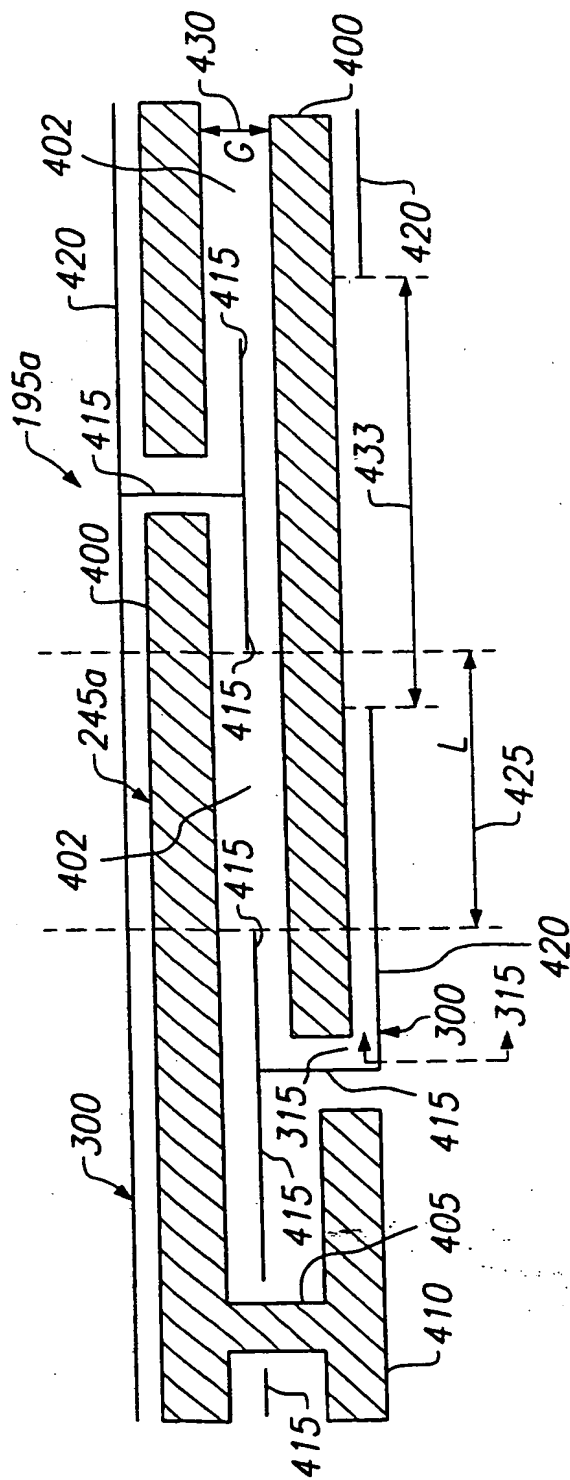
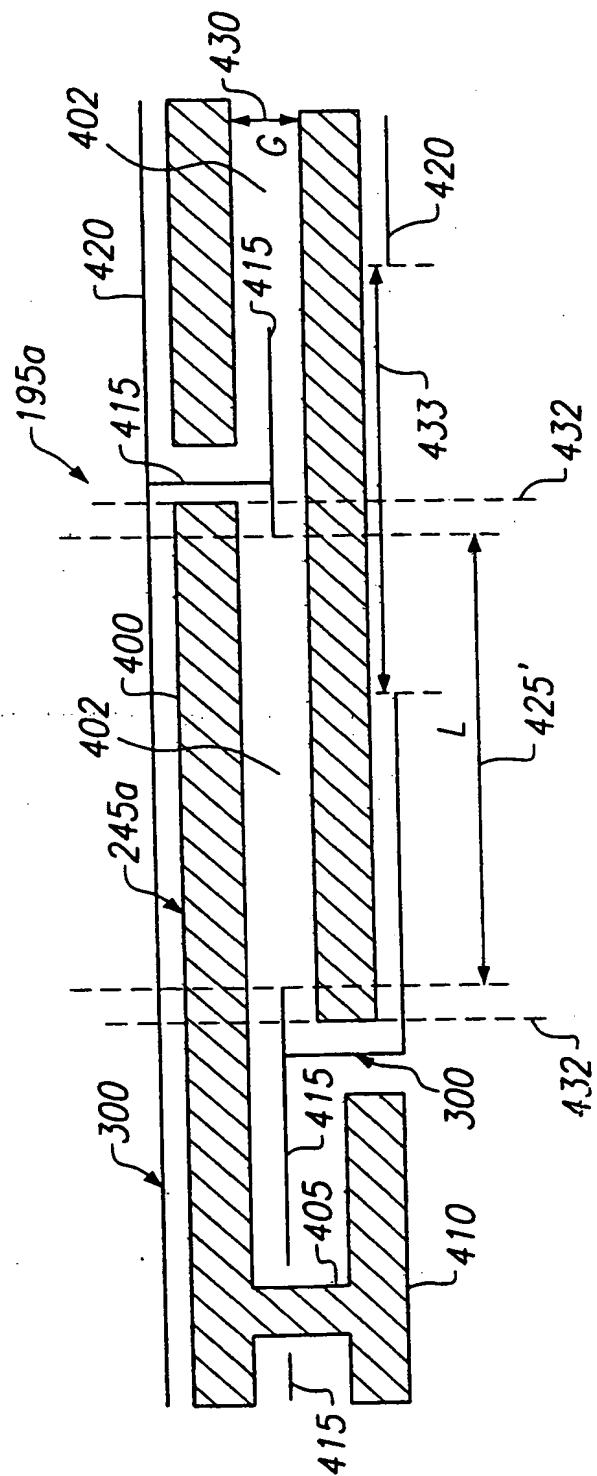


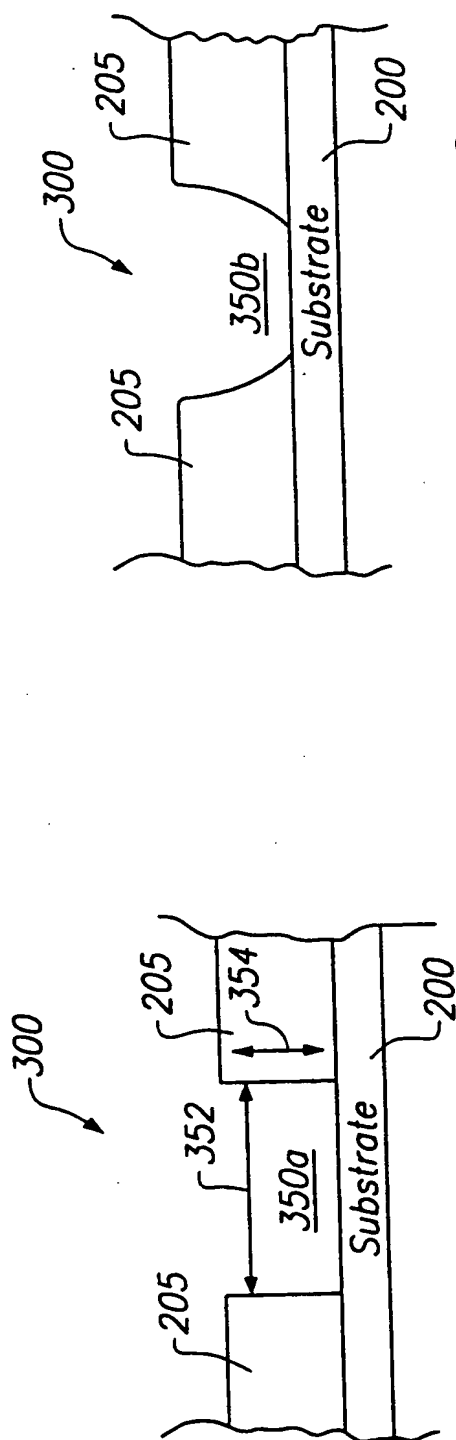
FIG. 4



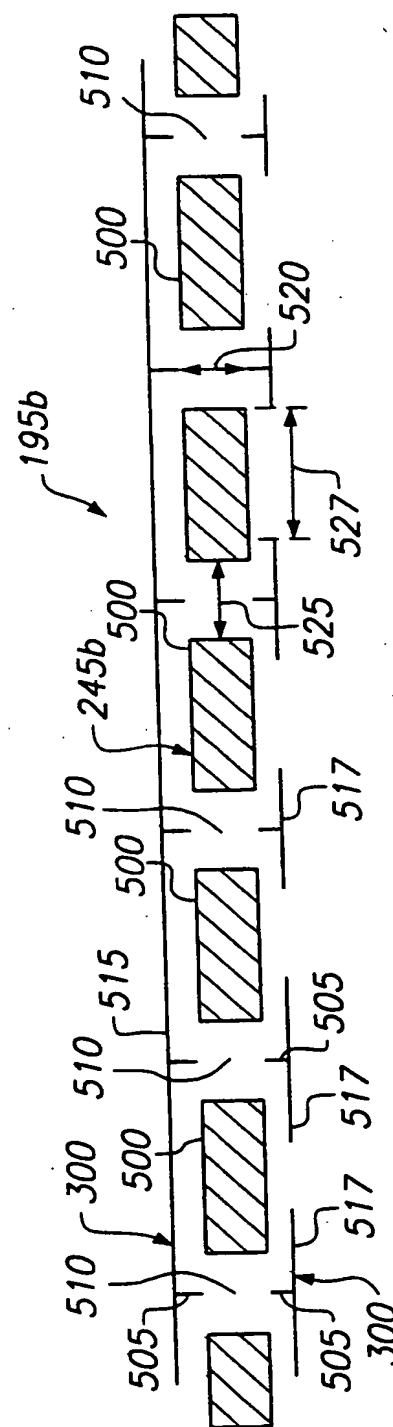
**FIG. 6**



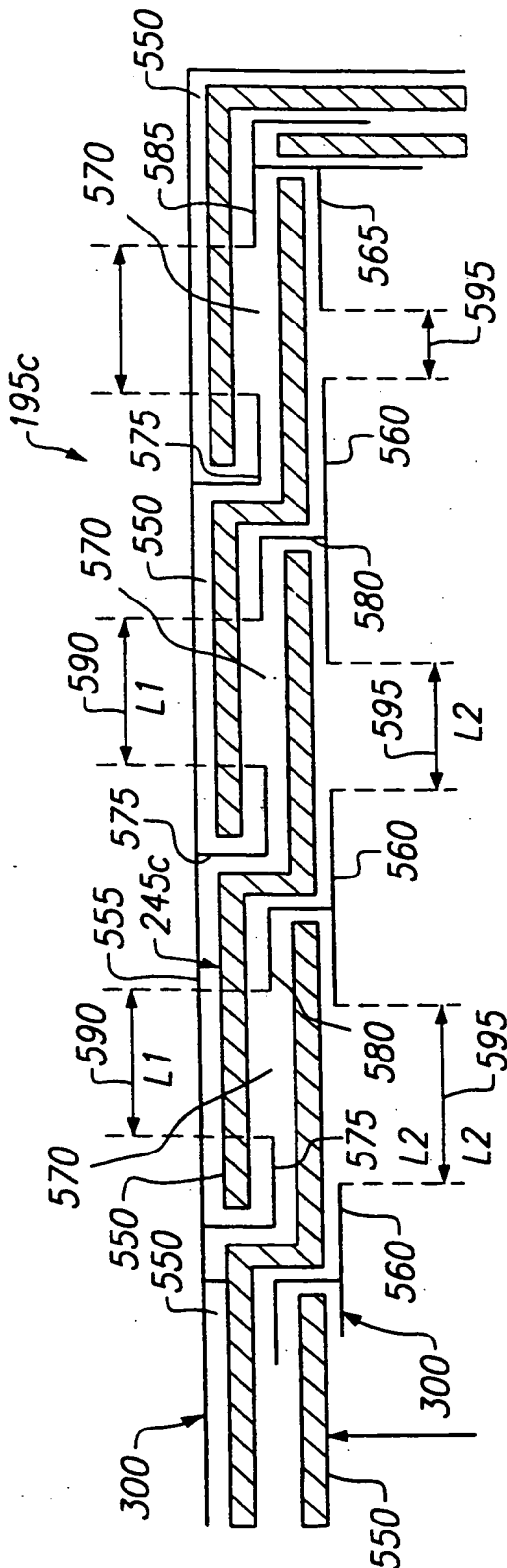
**FIG. 6A**



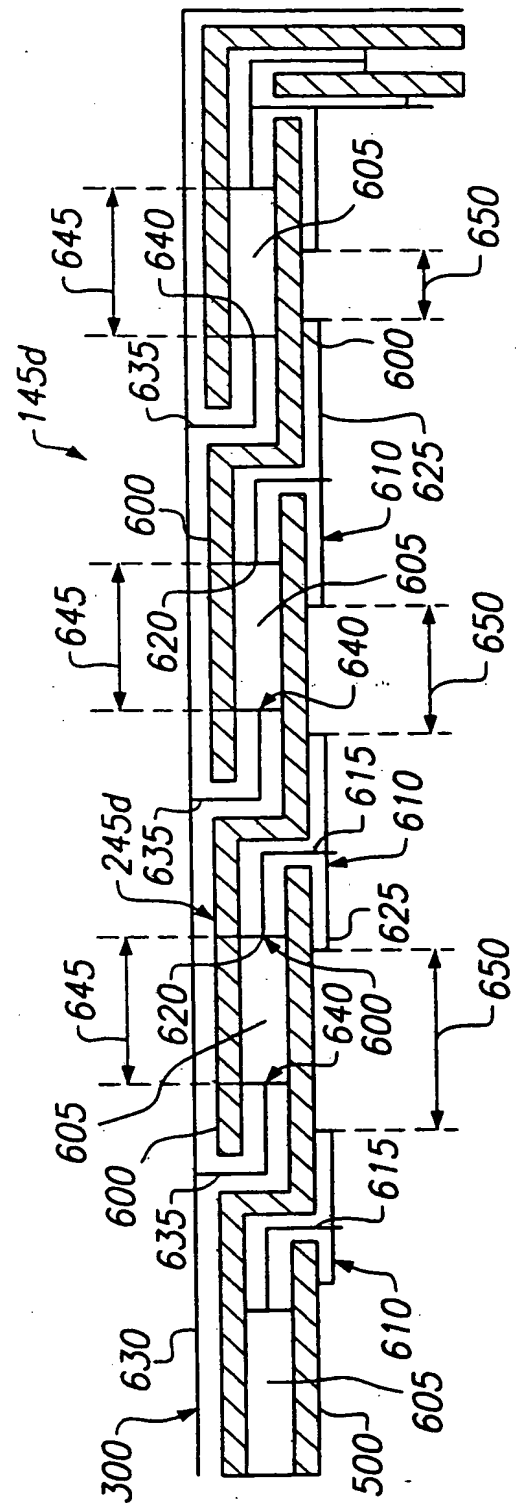
**FIG. 6C**



**FIG. 7**



**FIG. 8**



**FIG. 9**



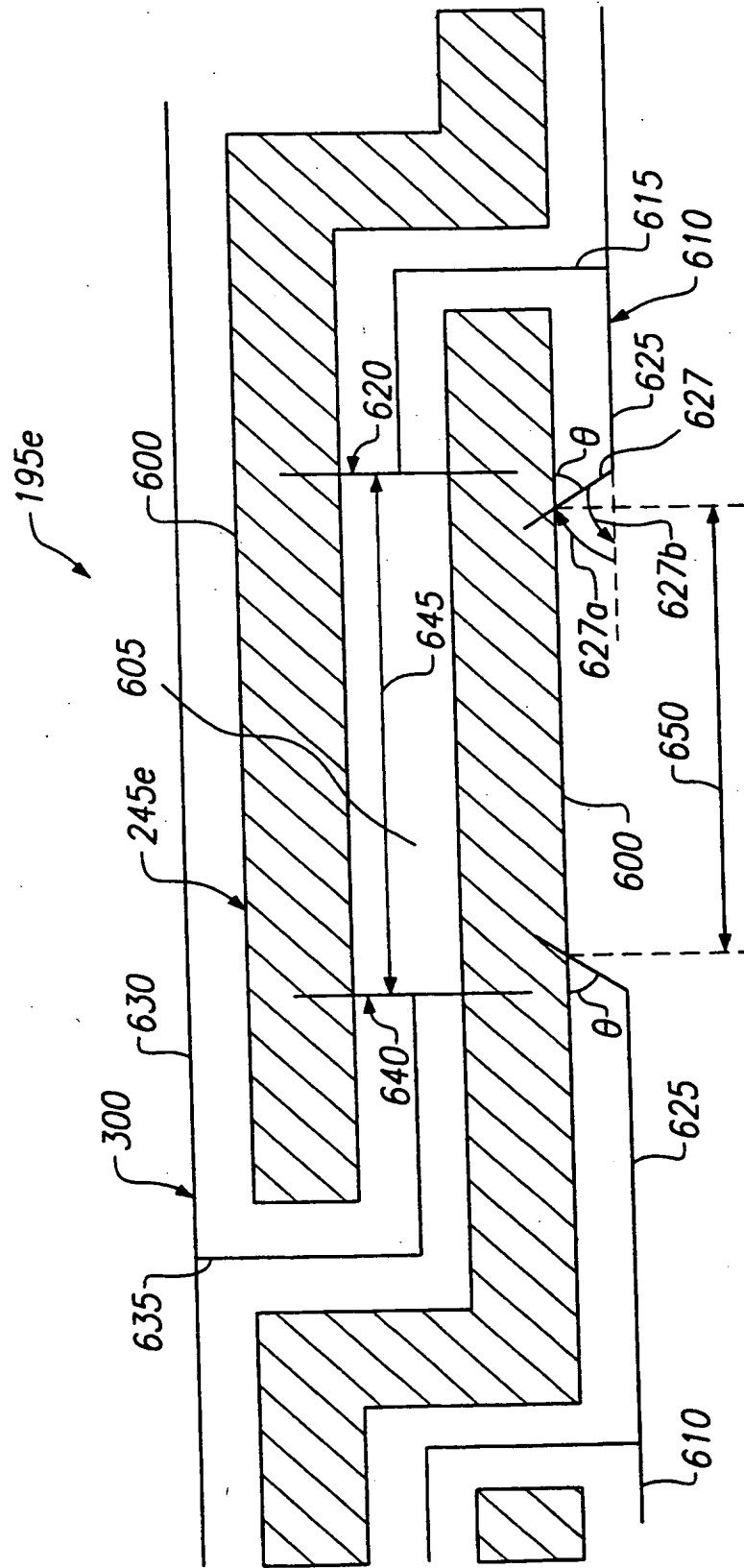


FIG. 10

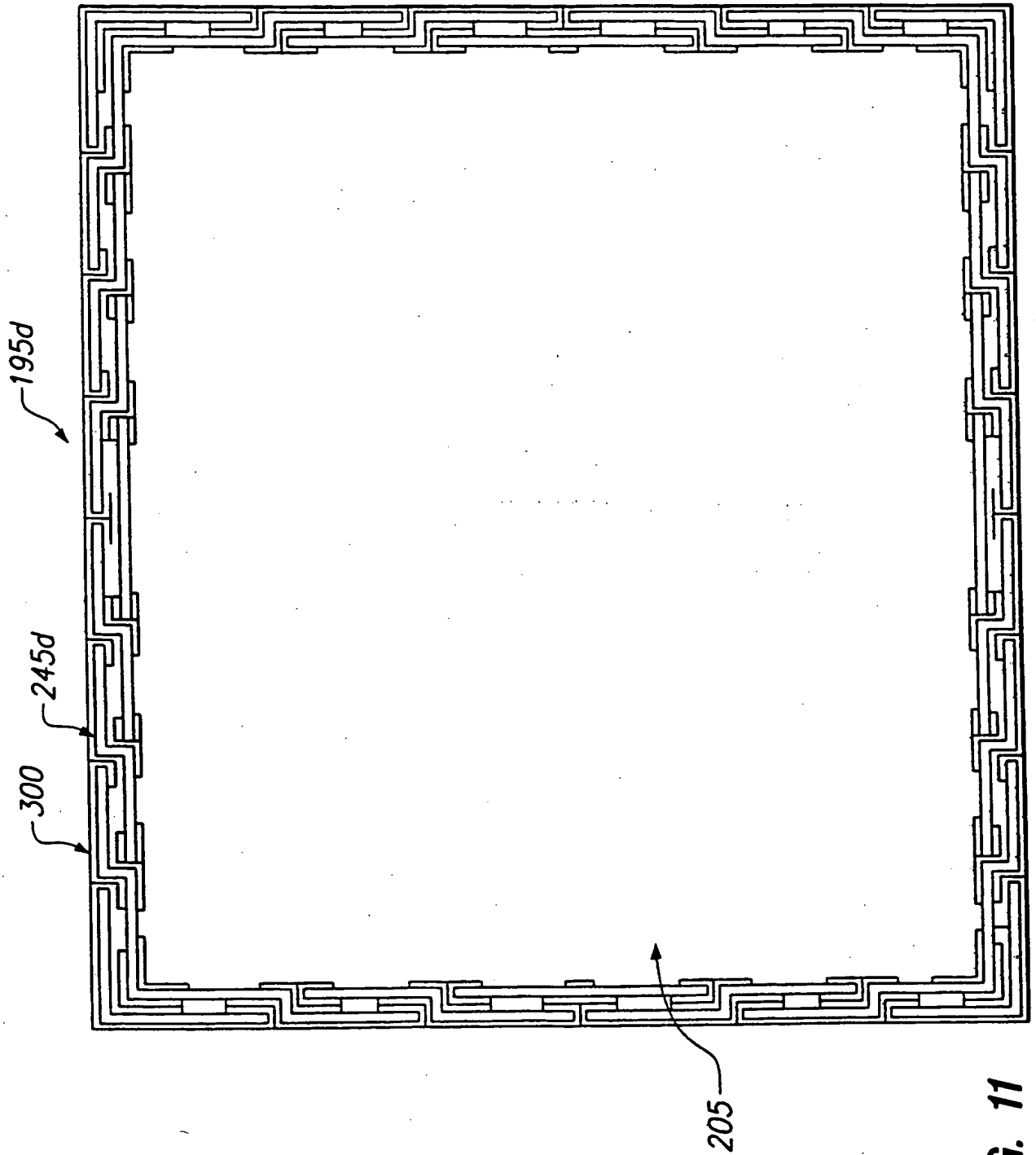


FIG. 11

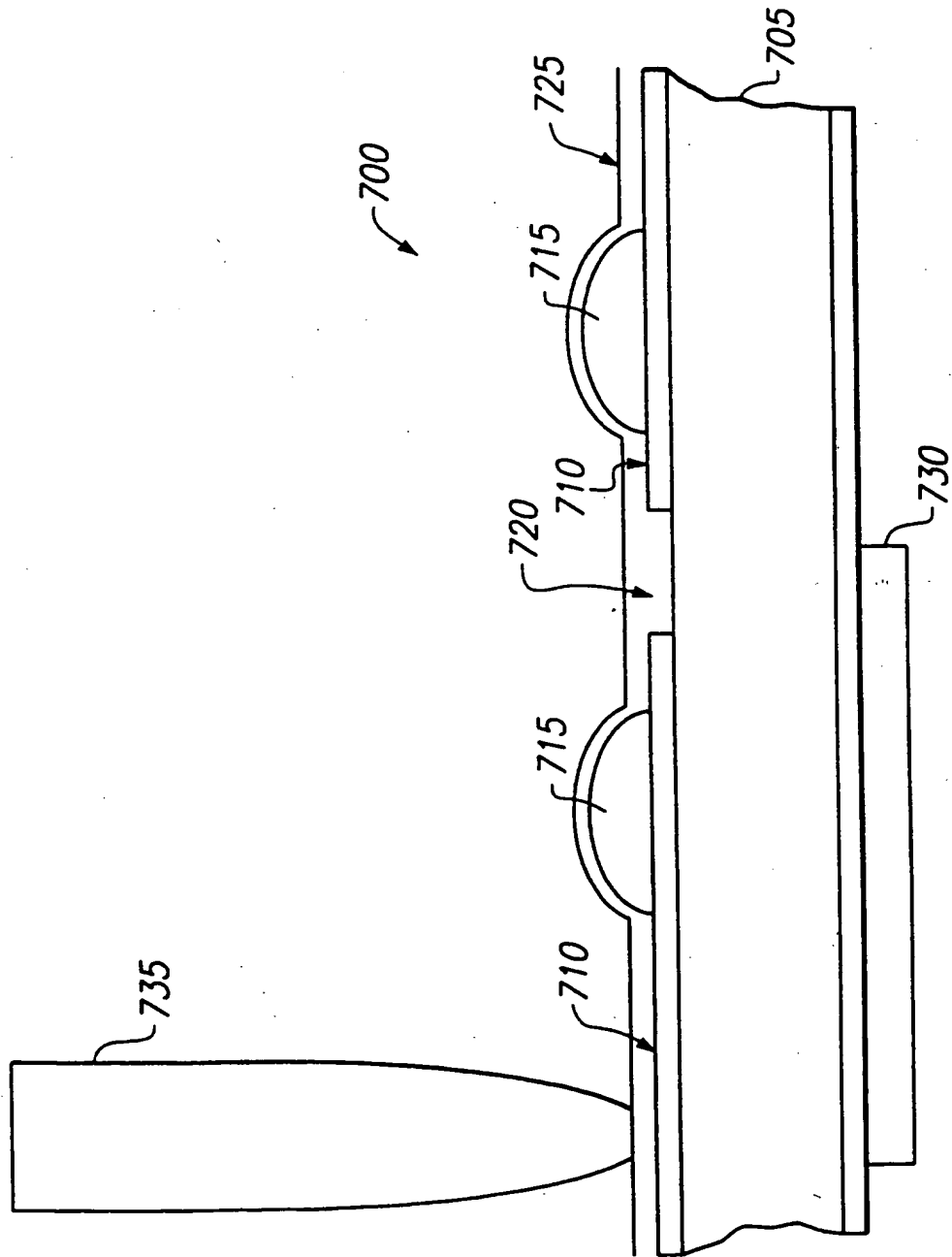


FIG. 12

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 98/26448

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 G06K11/12

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>US 4 822 957 A (TALMAGE JR JOHN E ET AL)  18 April 1989  cited in the application  see abstract  see column 4, line 17 - line 20  see column 4, line 40 - line 48  see column 7, line 30 - line 38  see column 7, line 52 - line 65  see column 8, line 5 - line 34; figures 4,5  see column 9, line 34 - line 49; figure 4A  see column 10, line 33 - line 61; figures 6,6A</p> <p style="text-align: center;">--- -/--</p>	<p>1-6,  9-15,19,  21</p>



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

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Date of the actual completion of the international search

12 April 1999

Date of mailing of the international search report

16/04/1999

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>WO 87 04553 A (INTERACTION SYST INC) 30 July 1987</p> <p>see abstract see page 4, line 19 - line 24 see page 21, line 1 - page 22, line 19; figure 5 see page 23, line 23 - page 26, line 11; figure 5A</p>	1-6, 9-15, 19, 21
A	<p>US 4 493 104 A (LUKIS LAWRENCE J ET AL) 8 January 1985</p> <p>see abstract see column 2, line 56 - column 3, line 36; figure 2</p>	1-6, 9-15, 19, 21
A	<p>US 4 725 695 A (MURDOCK BRUCE ET AL) 16 February 1988</p> <p>see abstract see column 6, line 11 - line 68; figures 1-3</p>	1-6, 9-15, 19, 21
A	<p>US 4 293 734 A (PEPPER JR WILLIAM) 6 October 1981 cited in the application see abstract</p>	1, 9, 13, 14, 21

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Information on patent family members

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